Cruise Report: Long-range Ocean Acoustic Propagation EXperiment (LOAPEX)

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This cruise owes its success to many people. The science team consisted of Jim Mercer (Chief Scientist), Rex Andrew, Patricia Cheng, John Colosi, Garth Engelhorn, Lyle Gullings, Bruce Howe, Fred Karig, Chuck Fletcher, Mike Wolfson, and Jinshan Xu. Bob Wilson, the Resident Technician, and Geoff Davis, the Computer Technician (both also members of the science team), were enormously helpful, as were Captain Chris Curl and his entire crew. On shore Linda Buck, Don Reddaway, Mike Macaulay, and Joe Wigton provided their usual wonderful support toward the operation of the NPAL network as a whole. In addition the shore support from the Scripps Marine Facility was critical during the mobilization phase. Also prior to the cruise at APL-UW, Keith van Thiel, Jason Gobat, and Craig Lee were responsible for preparing the Seagliders. During deployment, Charles Eriksen provided shore support and piloting of the Seagliders. Neil Bogue then took over and Jim Luby, with assistance from Jason Gobat, handled the remainder of the missions. We are also grateful to all of the NPAL Group for their support and many good suggestions. And finally, we appreciate the sponsorship of the Office of Naval Research, Code 321.

Abstract

This report documents the Long-range Ocean Acoustic Propagation EXperiment (LOAPEX) cruise aboard the R/V *Melville* conducted between 10 September and 10 October 2004. The LOAPEX cruise was coordinated with two other experiments, BASSEX led by Art Baggeroer of the Massachusetts Institute of Technology, and SPICEX led by Peter Worcester of the Scripps Institution of Oceanography. In addition to suspending an acoustic source from the R/V *Melville* at several locations in the eastern Pacific, LOAPEX utilized the North Pacific Acoustic Laboratory (NPAL) assets that were installed by APL-UW during the Acoustic Thermometry of Ocean Climate (ATOC) demonstration. LOAPEX has three primary scientific objectives:

1. to study the evolution, with distance (range), of the acoustic arrival pattern and in particular the range and frequency dependence of the spatial and temporal coherence
2. to determine the effects of the ocean bottom near the NPAL acoustic source located near Kauai, HI
3. to produce a thermal map of the Northeast Pacific Ocean

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1. Introduction

Background

Although serious investigations of long-range ocean acoustic propagation began with World War II, the genesis of our effort here began with our work on the Heard Island Feasibility Test. In that test electronically generated acoustic signals were sent and coherently received at very long ranges. This successful result led to the Acoustic Thermometry of Ocean Climate (ATOC) demonstration. The purpose of ATOC was to show that a small number of acoustic transmitters and receivers could adequately characterize variations in the heat content of an entire ocean basin. Although hindered by many new environmental regulations, ATOC demonstrated that basin-wide seasonal and climatic variations can be monitored using acoustic transmissions, and that it can be accomplished without endangering marine life.

When the formal ATOC program came to an end, the Office of Naval Research (ONR) began sponsorship of the North Pacific Acoustic Laboratory (NPAL). This program uses the acoustic source and receiver network established during ATOC to focus on basic research related to long-range acoustic propagation while at the same time allowing the continuation of the time series of climate related data. Every three years or so, ONR enhances the efforts of NPAL by funding additional experimental efforts. This is one of those years and three coordinated experiments were undertaken. They were SPICE04 (Peter Worcester, Scripps Institution of Oceanography), BASSEX (Art Baggeroer, Massachusetts Institute of Technology), and LOAPEX (Jim Mercer, Applied Physics Laboratory, University of Washington).

The SPICE04 installation cruise was conducted between 26 May and 18 June 2004 aboard the R/V *Revelle*. During this cruise two autonomous vertical line array receivers (VLAs), and two 250-Hz acoustic transceiver moorings (500 km and 1000 km from the VLAs) were deployed (*Worcester*, 2004). These four moorings will be in place until sometime during the summer of 2005. The primary purpose of the transmissions between the 250-Hz sources, transceivers, and the VLAs is an attempt to measure the "spiciness" of the ocean by acoustic methods. Ocean "spice" is a condition in which the water temperature and salinity offset one another to form a buoyantly stable water mass that has sound speed variability that mimics that of ocean internal waves. In addition to receiving the transmissions from the 250-Hz sources, the VLAs were programmed to receive transmissions from the NPAL fixed bottom-mounted acoustic source near Kauai, HI, and a similar acoustic source suspended from the R/V *Melville* during the LOAPEX cruise. The hydrophone arrays on the two combined VLAs covered most of the 5-km water column. We refer to one of the VLAs as the deep VLA (DVLA), located at 33.418920°N latitude and 137.682470°W longitude. The DVLA combines a 40-element, 1400-m long array (2150–3550 m nominal) with a 20-element, 700-m long array (3570–4270 m nominal) to span the lower caustics in the acoustic arrival pattern with a nominal spacing of 35 m. The DVLA was considered the primary receiving array for LOAPEX. The other moored array, the shallow VLA (SVLA), was moored 3 n mi due west of the

DVLA. The SVLA has a 40-element, 1400-m long array (350–1750 m) centered approximately on the sound channel axis. Both hydrophone arrays are being tracked by a network of surveyed bottom transponders. Mooring diagrams, provided by Peter Worcester, are shown in Figure 1.1.

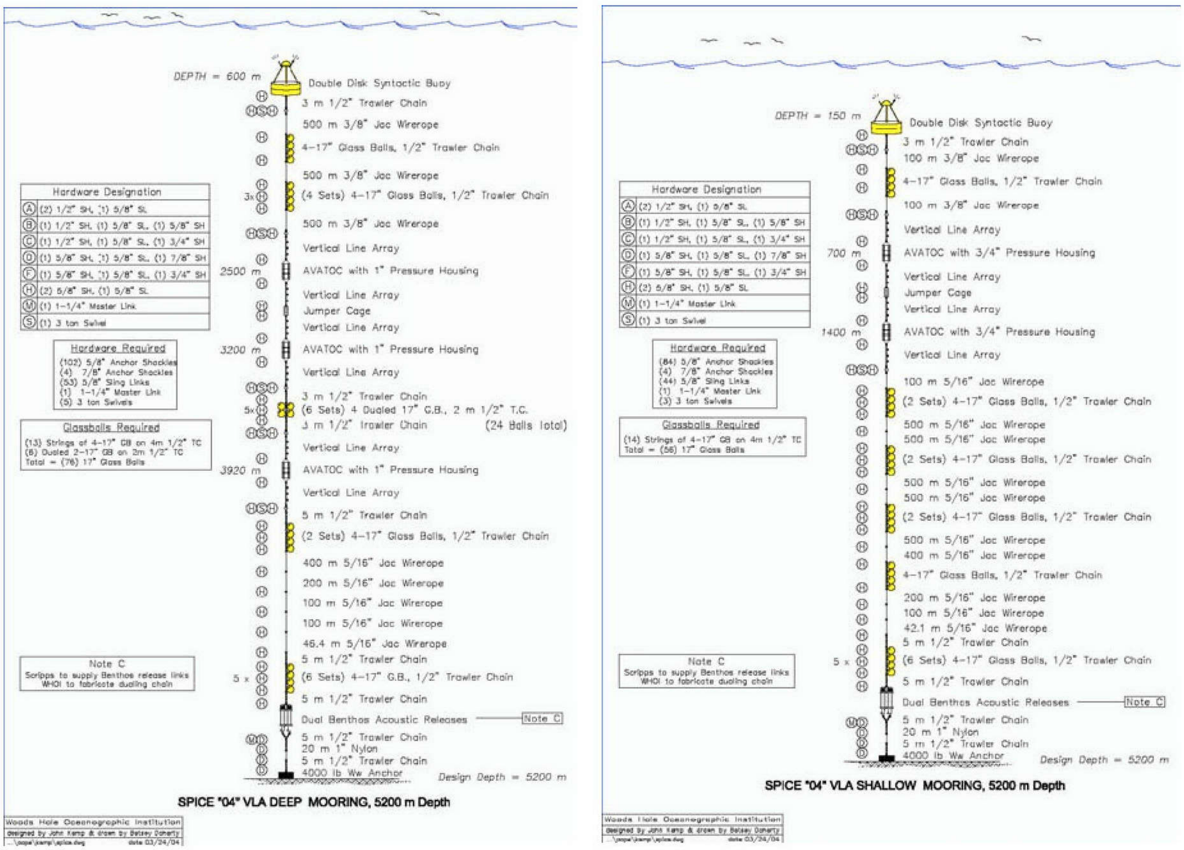

Figure 1.1. The deep and shallow VLA receiver moorings

The BASSEX experiment, conducted from the R/V *Revelle,* was coincident with the LOAPEX cruise. During BASSEX a horizontal towed acoustic array was used to collect receptions from the LOAPEX ship suspended source, the Kauai fixed source, and the 250-Hz SPICE04 transducers. The first phase of BASSEX concentrated on acoustic receptions affected by the presence of the Kermit Sea Mounts. The data is intended to reveal information about sea mount forward and backward scattering, as well as refraction and diffraction. Other phases of BASSEX focused on long-range horizontal coherence, characterization of the acoustic field near the Kauai source, and geo-acoustic inversions near Kauai.

The LOAPEX cruise was conducted aboard the R/V *Melville* from 10 September to 10 October 2004. The scientific objectives of LOAPEX are outlined in the following subsection.

Science Objectives

An acoustic signal arriving at a hydrophone array from a large distance (range) is spread out in space and time. In mid-latitudes the early part of the arrival is associated with steeper arrival angles and is often considered "ray-like" in that the arrivals are well characterized by frequency-independent numerical ray-tracing codes. The middle part of the acoustic arrival pattern is better characterized by acoustic modes ("mode-like"), where the final part of the arrival is highly scattered energy and is not well modeled by deterministic methods. One way of characterizing our objective is to say that we are studying the evolution, with range, of the acoustic arrival pattern. Ultimately, however, we wish to understand the range and frequency dependence of the spatial and temporal coherence, and reveal ways of improving the coherence. Both of the VLAs are important for this study.

A more specific science objective is to understand the acoustic energy that arrives near and below the critical depth (where the deep sound speed equals the highest sound speed in the upper ocean). In previous experimental work, both for NPAL and AMODE (*Dushaw et al.*, 1999), we observed anomalously high signal to noise ratios at these great depths. Some of the observed effect may be due to decreased levels of ambient noise, but apparently not all. For this work the DVLA and the four ocean bottom seismometers (OBS) that we deployed around the DVLA are important assets. Because the LOAPEX transmissions were made from a variety of stations (see the next subsection) we have the opportunity, using the distributed array of fixed bottom-mounted NPAL acoustic receivers, to take a "snap shot" of the heat content of the entire Northeast Pacific Ocean.

A third major objective for LOAPEX was to transmit signals in the vicinity of the fixed bottom-mounted acoustic source near Kauai. It is not known precisely what effect the bottom has on the receptions at the NPAL fixed hydrophone network. By suspending the LOAPEX source near Kauai and at the depth of the Kauai source, but not near the bottom, the receptions at the fixed arrays, and at the VLAs for that matter, can be compared with and without bottom effects.

Approach

The approach to meeting the scientific objectives of LOAPEX was originally described in the LOAPEX *Cruise Plan* (*Mercer and Howe*, 2004) and is illustrated in Figure 1.2. The figure and its legend describe and locate the primary assets of the experiment and show the eight stations occupied by the *Melville* during the cruise. The eight stations are shown as red dots and seven of them are on the main LOAPEX path indicated by the solid black line. These seven stations were nominally 50, 250, 500,

1000, 1600, 2300, and 3200 km from the VLAs (yellow dot). These distances provided the controlled range dependency sought in this experiment. It would have been desirable to achieve greater ranges but the location of the VLAs and the bathymetry at the western end of the path prevented this. At each of these seven stations the LOAPEX acoustic source (Figure 1.3) was suspended from the ship for several hours, typically one to two days. Two source depths were used at each of the seven stations, either 350, 500, or 800 m. An eighth station near Kauai was also taken. This final station provides a comparison of transmissions from 300, 500, and 800 m depth, while the source is far from the bottom, with transmissions from the bottom-mounted Kauai source.

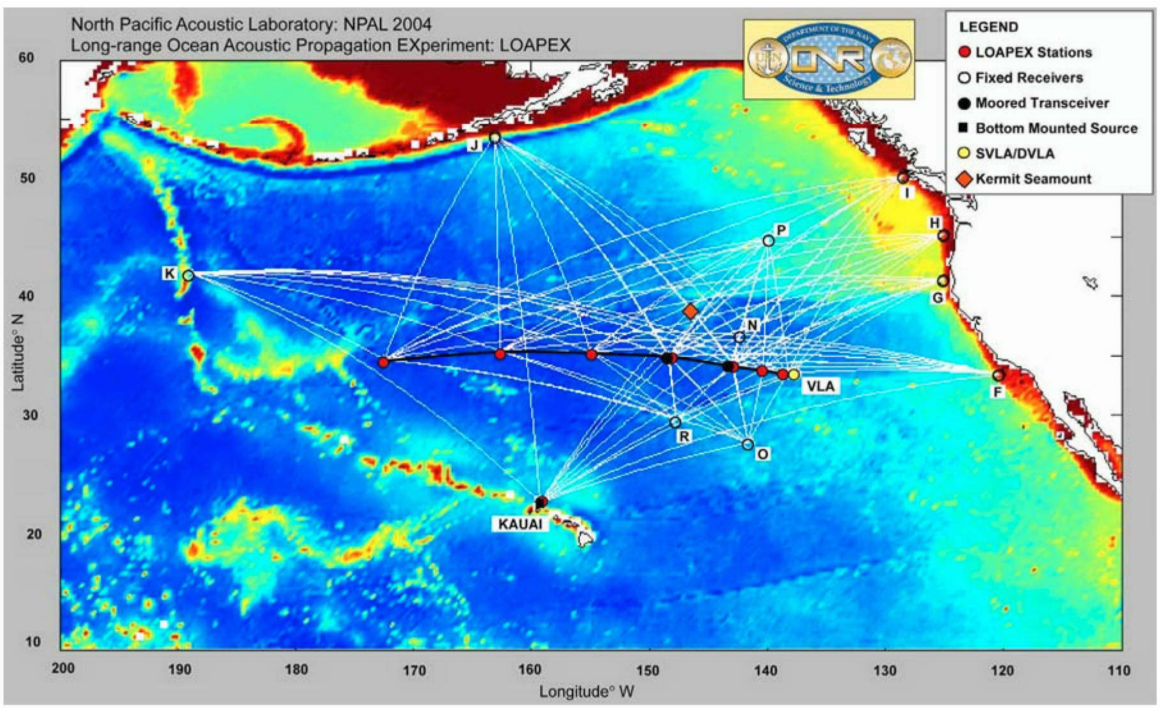

Figure 1.2. LOAPEX assets and geometry

Figure 1.2 also illustrates the paths from the LOAPEX stations, and from the Kauai bottom-mounted source location, to the permanently fixed acoustic receivers. These paths, along with the paths from the 250-Hz SPICE04 acoustic sources, allow us to produce a "snapshot" of the Northeast Pacific Ocean's heat content. Not shown on this figure are the locations of four OBS/hydrophone packages (see Figure 1.4). These four instruments were deployed to the bottom (water depth approximately 5000 m) in a rectangular pattern (see Figure 1.5) about the DVLA.

Figure 1.3. The LOAPEX acoustic source without its oil-filled boot (left) and with the boot, mounted in its frame (right). Four high-pressure air compensation bottles are mounted in the rectangular portion of the frame.

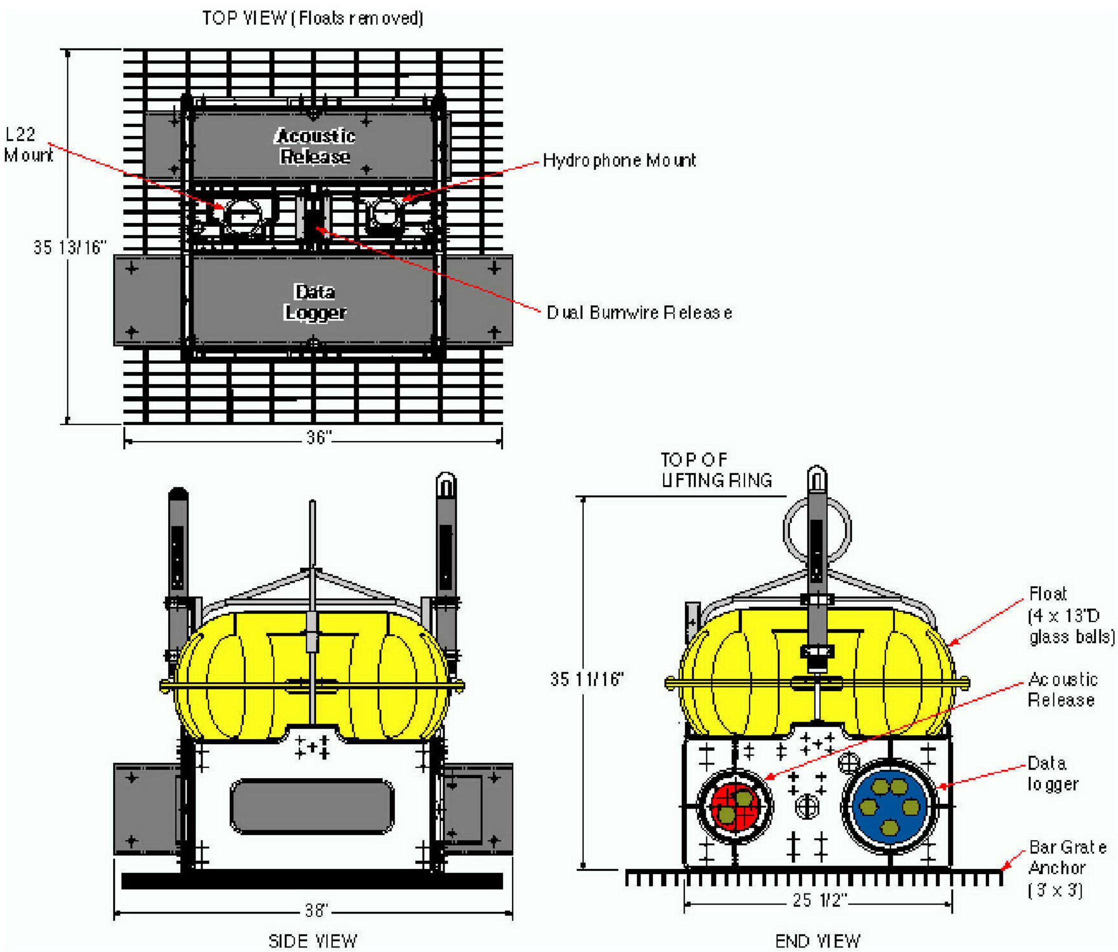

Figure 1.4. The LC200 ocean bottom seismometer package

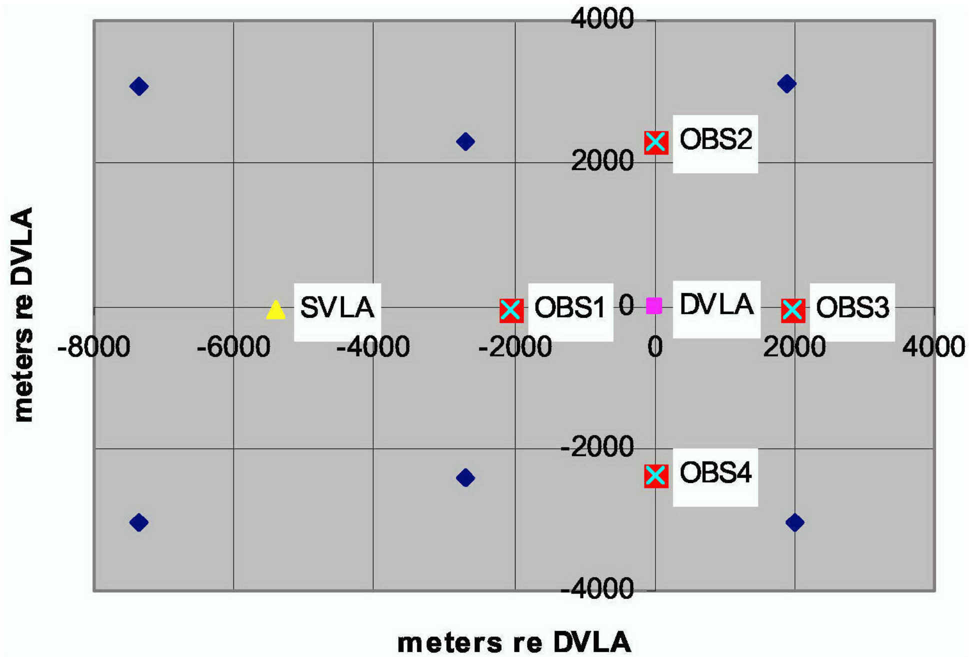

Figure 1.5. OBS deployments about the DVLA

These deep seismometer and hydrophone locations provide additional information on the deep shadow zone arrivals that we and others (*Butler*, 2003) have reported. The exact locations will be surveyed during the SPICE04 recovery cruise.

A description of the signals that were sent from each of the LOAPEX stations is provided in Section 3, and Appendix 2 provides log data for each transmission. A critical aspect of the acoustic source deployment was to obtain good, reliable data on the position and velocity of the source as a function of time. Section 4 provides a description of the various data types that were collected to determine the source position and velocity. Finally, Section 5 provides a description of the environmental data that were collected during the cruise. These data will support the numerical modeling efforts that will attempt to explain the acoustic data collected. The following section is a cruise narrative; although it covers the entire cruise, the primary purpose is to describe the activities at a typical deployment station and the atypical events at the first station.

2. Cruise Narrative

Mobilization

The mobilization for the LOAPEX cruise took place from 30 August to 9 September. This unusually long time period was due to the intervening Labor Day holiday weekend. The majority of the hardware used in this cruise came aboard in two 20-ft. containers. One of these containers, the science van, was partitioned into two halves. One half housed the acoustic transmitter and electronics, and the other half contained the deployment winch and the low and high pressure compressors. Figure 2.1 is a photograph of this container showing the winch and low-pressure compressor (blue) that supplies air to the deployment air "tuggers." The high-pressure compressor used to refill the air compensation bottles on the source is out of view behind the low-pressure compressor. This van was configured for easy portability to ships of opportunity. The second container transported the acoustic projector and stored ancillary equipment and spares. Each container weighed approximately 20,000 lb.

Figure 2.1. The aft end of the LOAPEX science van

After the containers were secured on the deck, the majority of the mobilization effort was spent testing the various systems to be used during the cruise. The critical equipment belonging to the ship included the stern A-frame, starboard A-frame, both of the ship's cranes, CTD/rosette, CTD level wind, gyrocompass, the P-code and C/A code GPSs, the multi-beam sonar, the Ocean Surveyor Acoustic Doppler Current Profiler, the ship's computer systems, and the ship's 400-VAC power. Several of the ship's systems

were damaged during a power outage that took place during the previous cruise. Necessary repairs were made and a sea trial during the mobilization confirmed the success of these repairs and provided an at-sea test of the ship's dynamic positioning system. After the sea trial additional repairs were made to the CTD level wind, to the ship's main crane, and the starboard A-frame. The personnel at the Scripps Marine Facility and the ship's crew worked very hard to ready the ship for an on-time departure.

The systems brought on board by the science team can be grouped into three main categories: those items directly related to the acoustic transmissions, those used to determine the position and velocity of the acoustic projector, and those items used to collect environmental data. Figure 2.2 shows the acoustic projector being lowered into the water during a dockside deployment test. The small white cylinder at the top of the projector is an acoustic valve. This valve is actuated remotely once the projector reaches its desired depth by sending a coded acoustic signal through the water. Once opened, high-pressure air stored in four 6,000-PSI cylinders in the lower rectangular section of the projector package is allowed to enter the interior cavity of the projector forcing out the sea water. This air provides greater compliancy for the movement of the projector's vibrating surfaces and results in greater efficiency.

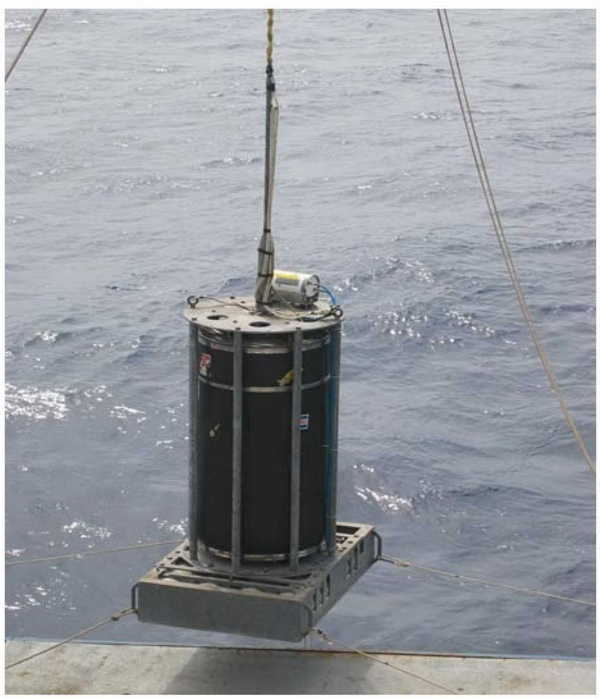

Figure 2.2. The LOAPEX acoustic projector

The projector is powered by a 48,000-VA Ling power amplifier that is housed in the forward section of the science van. Signals generated by a computer in the science

van are amplified and delivered to the 0.680 coaxial cable that is shown on the winch in Figure 2.1. Full power signals could not be sent dockside; however, a "dummy load" set up in the storage van allowed full power testing of the amplifier and signal generation systems during the mobilization. Just prior to this testing it was noted that the ship's 440/240 VAC transformer did not supply adequate voltage. A transformer purchased by APL-UW for an at-sea test in May 2004 (*Mercer*, 2004) solved the problem.

The acoustic system also included the four OBS that were deployed about the DVLA, and a monitor hydrophone system that used a powered spool for the hydrophone cable and special filters and amplifiers for signal detection. This calibrated hydrophone monitor system was used with each transmission during the cruise to determine the actual level of each transmission. A final component of the acoustic system was the WRC "sweeper" acoustic source (Figure 2.3). This unit was checked out aboard ship during mobilization with the help of David Horwitt, Matt Norenberg, and Peter Worcester, all of Scripps. The sweeper was brought as a backup and, fortunately, it was not required.

Figure 2.3. The WRC "sweeper" acoustic source

The following equipment supported the determination of the projector's position and velocity during deployments: a MicroCat pressure sensor, an S-4 current meter, two acoustic interrogators, several Benthos acoustic transponder balls, two Benthos deck boxes, and a C-Nav GPS. The C-Nav GPS receives orbit, time, and troposphere propagation corrections while at sea and provides decimeter accuracies. These systems all checked out dockside and their performance at sea is discussed in Section 4.

Systems brought aboard to acquire environmental data included the underway CTD (UCTD) provided by Dan Rudnick (Scripps), two APL-UW Seagliders, and approximately 100 XBTs. The XBTs could not be sample tested dockside, but the ship's XBT launcher was tested. Section 5 discusses the performance of these systems at sea.

In summary, we left port on 10 September 2004 with all necessary systems having been satisfactorily tested.

Cruise Summary

The R/V *Melville* left San Diego on 10 September on route to the location of the DVLA. The transit took approximately four days. During the transit a significant effort was made to train all science personnel on the deployment and operation of the UCTD system. We arrived at the DVLA, actually OBS site #4 shown in Figure 1.5 and detailed in Table 2.1, around 10:30 PM on 13 September. Our first in-water effort was to wire test the OBS releases. The planned depth for the wire test was 4000 m but the wire jumped the sheave on the winch and the lowering was terminated at 3000 m. All of the releases tested satisfactorily at this depth. With some effort the wire was replaced on the sheave and the rosette assembly of releases was brought back to the surface. All of the OBS electronic assemblies passed their bench tests except #069. After the pressure case was opened and the battery termination reconnected, the fault (`could not access the disk`) disappeared.

Table 2.1 OBS deployment data

OBS/Rel. Ser#	Site#	Drop Time (UTC)	Latitude N	Longitude W
063	4	0825	33 23.8505	137 40.9471
023	3	0902	33 25.1121	137 39.6872
061	2	0935	33 26.3790	137 40.9503
069	1	1017	33 25.1104	137 42.2816

We arrived at LOAPEX Station T50 early the next morning, 14 September. (Note: the first seven LOAPEX Stations are designated by an upper case "T" followed by the nominal distance in kilometers from the station to the DVLA.) As this was our first station it was somewhat anomalous is several respects. To begin, we found that the CTD was not functioning properly. We also had to make final at-sea calibration adjustments for the acoustic transmission source levels. And third, two APL-UW Seagliders were launched from this station. Before continuing with a general summary of the cruise, a short discussion of each of these issues follows.

Because of the early arrival at Station T50, the CTD cast was begun well before breakfast. A problem in the downcast developed at about 2600 m. There were multiple fault indications and the pump stopped. When the CTD was brought back up to about

100 m the pump started again. Furthermore, some of the faults were traced to a computer problem. Nevertheless, when the CTD was lowered to a depth of about 1100 m the pump stopped again. The CTD was brought aboard and the problem was found to be a faulty connector between the conductivity sensor and the pump. A replacement cable/connector was located and installed. Unfortunately, the next CTD deployment at Station T250 revealed additional problems with the CTD. The CTD was recovered and more inspections began. Later in the day a test revealed that the main cable from the CTD unit had an open lead. The cable was repaired and another CTD cast at Station T250 proved satisfactory. All remaining CTD casts during the cruise were satisfactory.

The Environmental Assessment (*Raposa and Messegee*, 2004) for LOAPEX was based upon an acoustic source level of 195 dB re 1 μPa at 1 m, therefore it was necessary to conduct calibration measurements that allowed a gradual approach to this level. Deployment depths of 350 and 800 m were scheduled for each station and two primary signal types, a standard M-sequence and a prescription FM (PFM) slide, were planned for each depth. (See Section 3 for details on the acoustic signals and transmissions.) It had been previously decided to limit the level of the M-sequence to 194 dB while the projector was at a depth of 350 m to reduce stress on the projector. Calibration measurements were made using a calibrated hydrophone suspended to a depth of 575 m, halfway between the deployment depths.

At Station T50 the projector was initially deployed to a depth of 800 m. Following some very brief low-level testing with a 65-Hz CW signal we switched to a short 90-sec M-sequence. Two methods of adjusting the transmitted source level were used. One method was to adjust the power amplifier drive (PA drive) level and the other was to numerically scale the computer software files that generated the low-level transmissions. We started with a 195-dB file (for 800 m) with the PA drive setting at half its expected value of 152. We anticipated a source level of 189 dB and got just that. We then increased the PA drive setting to 304 and got a source level of 194.2. We considered this satisfactory for the time being and moved on to the PFM signal. We again set the PA drive to half of its expected value for a 195-dB PFM transmission at 800 m and measured a source level of 190.2 dB. The next test was at a PA drive setting intended to produce a 195-dB signal and the result was a source level of 195 dB.

Later the following day, after the projector had been raised to a depth of 350 m, we began a series of tests to confirm that the pre-programmed signals would produce the correct source levels at this depth. Because of the difference in ambient pressure between 800 m and 350 m, the projector's characteristics change appreciably. At 350 m our plan was to transmit the M-sequence at 194 dB and the PFM at 195 dB. We began by transmitting a 90-s M-sequence designed for 350 m with the PA drive dial at the 152 position (half that planned for a 194-dB signal). The result was 188 dB, right on. We then transmitted another 90-s M-sequence with the PA drive dial at 304. The result was 194 dB.

The next transmission was a calibration test for the PFM. Again with the PA drive dial at 152 we measured a source level of 190.7 dB. This was a little higher than

expected so we calculated that a PA drive setting of 249 would be appropriate for this signal and this depth. The result for another 90-s PFM with the dial at 249 was 195.7 dB. This was considered to be within acceptable accuracy.

The M-sequence source levels were calculated using an evolved form of Kurt Metzger's software. The travel time from the source to our monitor hydrophone was measured for each transmission. Unfortunately Metzger's software contained an unknown delay time. The estimated distance between the source and the monitor hydrophone based upon wire and deck measurements was 228 m. The acoustic distance measurement, with the unknown time delay, yielded 286 m while the source was at a depth of 800 m and 271 m while the source was at 350 m. The difference between these values and 228 m was considered to be too large and the cause was expected to be the unknown delay time. While at site T50, which is very close to the VLA, we decided to stick with the acoustic measurement because it erred on the safe side; i.e., calculations of source level were about 2 dB higher than otherwise.

On route to Station T250 we located Kurt Metzger's old documentation, which indicated that he used a delay time of 27 ms. On the other hand, Rex Andrew's numerical model calculations of the acoustic source predicted 13 ms delay time. The difference was small and was equivalent to about 1 dB difference in source level calculations. We used the average value of 20 ms to limit the error from this issue to 0.5 dB.

While at Station T50 we made twelve transmissions at 800 m not counting the short calibration transmissions. Two of these transmissions were 20-min PFMs, one was an 80-min M-sequence and nine were 20-min M-sequences. We also made eight transmissions at 350 m not counting short calibration transmissions. All eight were 20-min M-sequences. A log of the transmissions at all stations is given in Appendix 2.

The third unique activity at Station T50 was the launching of the Seagliders. Preparations for launch were significant and had to be coordinated with the Seaglider pilot stationed at the University of Washington in Seattle. Communications were accomplished with a portable Iridium telephone. The first glider (#023) was launched at about 10 AM and departed successfully. The second glider (#022) was launched at about noon and although the launch itself was straightforward, the glider immediately turned toward the ship once it was released. Otherwise this glider also departed from the area after passing its post deployment tests.

Around mid-day we learned that Seaglider #023 was experiencing difficulties. Apparently erratic roll angles were occurring during the deep dives. The pilot's plan in Seattle was to leave the glider on the surface in the hope that we could attempt a recovery. After recovering the source at T50 around 7 PM, we planned to transit to the Seaglider position. The Seaglider can call in its GPS position every two minutes while on the surface. We learned, however, that after its last surfacing it was commanded to complete a few shallow dives. We believe the intention was to minimize drift of the glider while we were on route to pick up the glider. Unfortunately, the glider never re-contacted the pilot. Even though it was expected that the glider was not on the surface,

using its last known position and measurements of the surface current we made an estimate of its position and headed for that location. We arrived at this site around 7:45 PM and began transmitting an acoustic signal with the Benthos deck box and transducer. There did seem to be some consistent reply signals arriving with round trip travel times of 6 s. The ship was moved in a southerly direction in an attempt to reduce this travel time. However, when the move was completed, around 10:15 PM, the acoustic signal could not be recovered. It was decided to abandon the search for Seaglider #023. The rationale for doing so was as follows: 1) the likelihood of the glider being on the surface, and not contacting the pilot was considered very small; 2) even if it was on the surface, there was no acoustic signal at this time; and 3) even if the acoustic signal were regained by moving to some other location, it would be nearly impossible to home in on the device to a distance that it might be spotted visually at night in any reasonable amount of time. We departed the site at 11 PM on route to Station T250. While at T250 we received news that Seaglider #023 had reported in and was apparently operable. Additional information about the progress of the two Seagliders is contained in Section 5. As of this writing, both Seagliders are approaching Kauai, HI, for pick up in March 2005.

While on route to Station T250, we began the routine of making various environmental measurements. The most challenging of these were the UCTD measurements. Typically, three people supported the process around the clock while we were underway. When the UCTD probe is deployed, a tether line pays out from the probe and from a commercial fishing reel mounted on a davit. This allows the probe to "fall" freely while the ship is moving. A UCTD cast was completed approximately every 30 min. Generally the casts went to a depth of 300–400 m. When a cast was recovered the probe was brought into the lab for data extraction while the tether bobbin was rewound for the next cast. Figure 2.4 shows the bobbin being rewound in a special purpose jig. We started with two good UCTD probes and lost one early on due to fraying of the tether. We continued UCTD measurements until our approach to Station T2300 on 26 September. We decided to stop casting the UCTD as this time to ensure that we could bring back the remaining probe for post cruise calibrations. A total of 174 UCTD casts were completed. Up to this time we had been launching XBTs every 50 km, but with the cessation of the UCTD, we began deploying XBTs every 25 km. Section 5 contains a discussion of these data. We also collected SeaBeam bathymetric data while in transit; Appendix 3 presents these data.

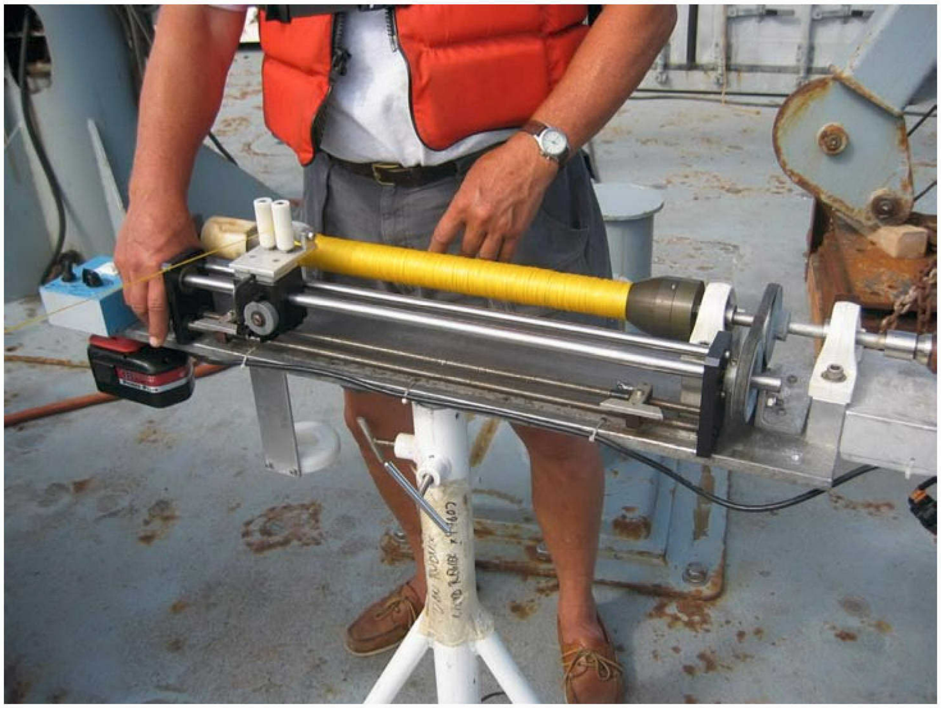

Figure 2.4. Rewinding the UCTD tether on the bobbin

The first event for a typical LOAPEX station was the deployment of a Benthos transponder ball. This actually occurred while we were approaching the station at a distance of roughly 5 km. The purpose of the transponder ball was to provide independent data on the motion of the ship and projector along the path back toward the VLAs. These data are discussed in Section 4. More often than not we arrived on station in the early morning hours. The first order of business was to conduct a full-depth CTD cast with water samples. This generally took about 4 hr. Once the CTD was back aboard we began the deployment of the calibrated hydrophone and the acoustic projector.

The calibrated hydrophone was lowered using the "hydro" boom and winch wire. A 500-lb weight was attached to the end of the wire to reduce streaming. The hydrophone cable itself was taped to the wire every 5 m or so and the hydrophone cable was spooled from a powered reel (Figure 2.5). The hydrophone itself was supported in a metal frame with a bungee cord to reduce strumming and the frame was taped to the lowering wire. Just before the calibrated hydrophone reached its desired depth of 575 m a small transducer was attached to the wire so that it would be at a depth of about 6 m. This transducer was used with a Benthos deck box to interrogate the transponder ball that was dropped to the bottom 5 km before reaching the station.

Figure 2.5. The powered spooler for the hydrophone cable

The deployment of the acoustic projector followed. The projector has four high-pressure gas bottles stored in its base. These bottles are filled with air between deployments. Because the projector weighs approximately 5000 lb, its deployment at sea requires great care. Figure 2.6 shows a projector deployment. Just prior to lifting the projector off of the deck, the S-4 current meter and a 20-lb weight were lowered by hand on a 10-m tether that was attached to the bottom of the projector frame. When the source reached a depth of about 20 m the MicroCat probe and the acoustic interrogator were mounted above the projector. The S-4 current meter, the MicroCat, and the interrogator were all intended to provide data on projector motion. Their results are discussed in Section 4.

While the projector was being deployed it was controlled by four tag lines. Two of these lines were powered by air-tuggers, the other two were held by hand. The projector was then lowered to the deepest depth to be used at that station. When the projector reached the desired depth, a small transducer was lowered over the stern to a shallow depth and a signal was sent to the acoustic valve to open the gas bottles. The gas bottles vented air into the interior cavity of the projector providing greater compliancy for

the transducer. Filling this cavity usually took about 30 min. Eventually contamination in an in-line filter in the gas system manifold apparently led to difficulties in pressurizing the projector at 800 m.

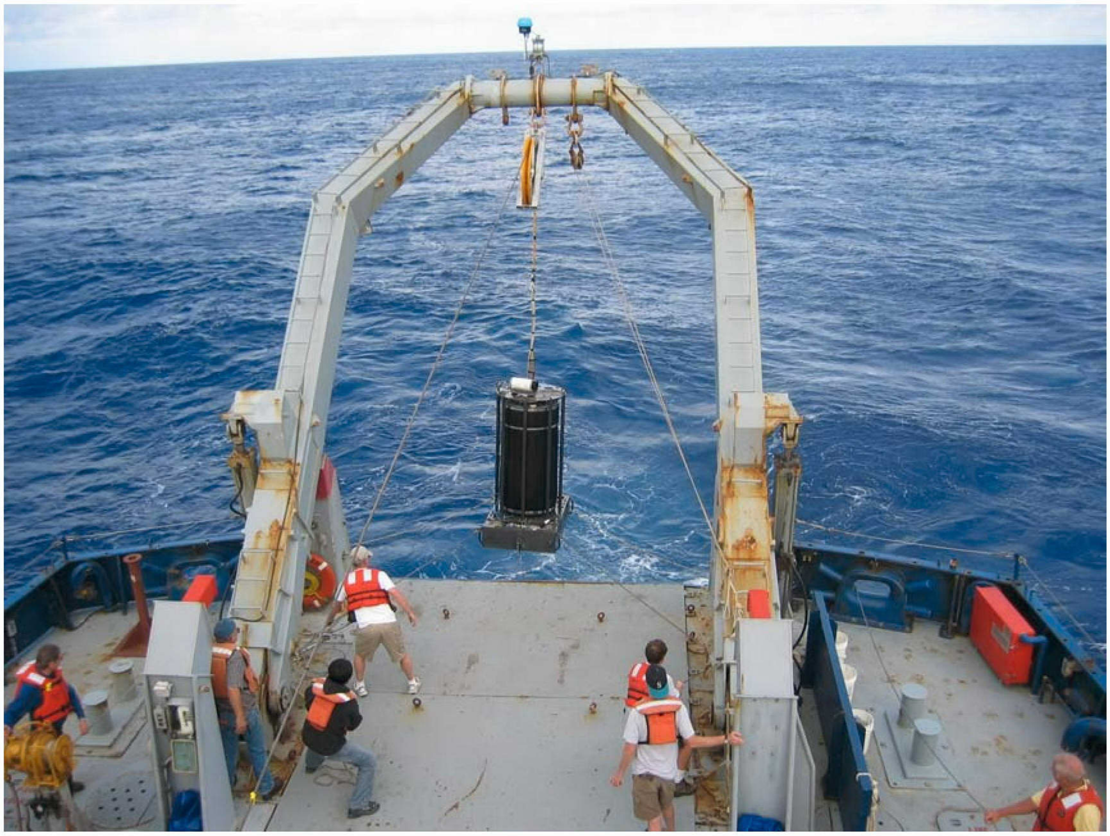

Figure 2.6. Deployment of the LOAPEX projector

The process of pressurization is described in greater detail in Section 2. However, once this process and initial status checks on the projector were completed, the series of planned transmissions began under computer control to ensure the exact time of transmission. Because the programmed reception times at the VLAs could not be modified once they were deployed, the transmission times aboard the ship were adjusted to account for the in-water propagation times. Nevertheless, the transmission schedule followed a 12-hr rotating sequence. For example, the transmission to be received at the VLA at 0000 hours UTC was a 20-min M-sequence. This was followed by three more 20-min M-sequences separated by 1 hr. The next transmission, also 1 hr apart, was a 20-min PFM. This was followed by an 80-min M-sequence, and then six additional 20-min M-sequences, all 1 hr apart, which completed the 12-hr schedule.

A typical LOPEX station provided a transmission window that included on average about 30 transmissions. Roughly half of these transmissions at each station were from the more axial depth of either 800 m or 500 m and the other half were from a depth of 350 m. Often a transmission opportunity was lost while the source was being raised from a depth of 800 m to the shallow depth of 350 m. At the final station near Kauai we transmitted at all three depths and also substituted several "Pentaline" transmissions; again, the details are provided in Section 3.

The reason we changed the deep deployment from 800 m to 500 m is that it became clear at Station T1000 that we were getting a reduced source level at 800 m, although nominal values were achieved at 350 m. The source level at 800 m was only about 190 dB. We now believe that this may have been due to contamination in the acoustic air valve system. At station T1600 we deployed the source to 900 m and pressurized it for 90 minutes. We then conducted an impedance test at this depth and in 100-m increments up to 400 m and then finally at 350 m. Based upon this test it appeared that we could achieve the expected performance at 500 m and shallower. Hence for Stations T1600, T2300, and T3200 we kept the deep deployment to 500 m. While in transit to the Kauai Station we had time to investigate the problem of low source level at 800 m. We filled the projector with additional oil, and we tried banding the supporting members of the frame to isolate the cause of an additional resonance in the impedance data. Neither of these approaches was fruitful. Due to the relatively high transit speed to Kauai we arrived several hours before the transmission window would open. We deployed the source to 800 m to check its performance. Because the pressurization process (as monitored by the changing impedance) seemed excessively slow, we brought the projector back to the deck. We noted that the gas pressure in the bottles had only gone down to 4000 psi from the initial pressure of 4500 psi. This meant that only one quarter of the interior cavity of the projector had been voided. Upon disassembly of the air pressure regulator valve we found significant contamination. Why contamination was so much more important at 800 m than 500 m is not known. The source was redeployed to 800 m and the pressurization process improved greatly although we expected that not all of the contaminants from the entire system were removed. The resulting source levels for this station at 800 m were 194–195 dB.

A more detailed day to day summary log of the cruise is provided in Appendix 1.

3. LOAPEX Acoustic Signals

Signals

There were seven signals used for the primary LOAPEX long-range transmissions, and two additional signals for local engineering measurements. These signals are described below.

Long-range Transmissions

M-sequences

The signal denoted M68.2 was the full power M-sequence used at 500 m and 350 m, and M75(195) was the full power M-sequence used at 800 m. It appeared in simulations that the best transfer of electrical power into radiated acoustic power occurred when the M-sequence carrier frequency was about 6–8 Hz above the resonance frequency of the transducer. Because the transducer resonance frequency varies with depth, we chose a carrier frequency of 75 Hz for 800-m transmissions and 68.2 Hz for 350-m transmissions. These depths were considered close enough that it seemed adequate to use the 68.2-Hz carrier signal at 500 m, too.

The choice of shallow depth carrier frequency involved several compromises. Because the computer digital-to-analog subsystem could only be programmed for integer sample rates, the requirement for a periodic waveform dictated that the waveform contain an integral number of carrier periods. This effectively quantized the allowable carrier frequencies. In addition, the VLA receiver scheduling was pre-programmed to collect 40 M-sequence transmissions (for the 20-min signals) with 75-Hz carriers: M-sequences with an alternate carrier frequency would not fit an exact number of sequences into the pre-programmed collection window. A frequency of 68.2 Hz was considered an adequate compromise that nearly filled the collection window with whole waveforms and with little remainder.

Simulations suggested that it might not be possible to radiate 195.0 dB re: 1 μPa @ 1 m broadband from the transducer at shallow depths without exceeding the stack stress safety limit. There appeared to be no problem for the source at 800 m nor at 500 m, but possibly at 350 m. Hence, the signal designed for 350 m depth was scaled down so as to achieve only 194.0 dB re: 1 μPa @ 1 m.

Table 3.1. M-sequence parameters

	M68.2	M75(195)
filename	M194.350	M195.800
law [octal]	2033	2033
digits	1023	1023
carrier [Hz]	68.2	75
cycles per digit	2	2
modulation angle [deg]	88.209215	88.209215
duration [seconds]	30.0000	27.2800
initial digits	00 00 00 00 01	00 00 00 00 01
max [quanta]	1271	1241
min [quanta]	–1275	–1242
rms [quanta]	747.89	727.79

The raw input files for the transmitter are in a custom format. These signals are also available in standard Microsoft ".wav" format files as follows:

Table 3.2. M-sequence file names

original file	.wav file
M194.350	M194.350.wav
M195.800	M195.800.wav

A custom MATLAB program, `npalwavread.m`, was created to access these .wav files. (The routine `wavread.m` supplied with the stock MATLAB distribution does not recognize the NOTE chunk, which is used in this file to retain signal construction parameters that formerly appeared in the old-style file headers.)

Several representative features of these M-sequences are shown in the following figures. Figure 3.1 shows a short section of the M195.800 drive signal and several corresponding internal transducer waveforms. These waveforms were produced by calculating the theoretical impulse response (based on the 800Special equivalent circuit model of the transducer) from input drive signal to internal waveform, and then filtering the input drive signal. The internal quantities are stack voltage, auto-tuner current, and stack stress. This figure shows several drive signal phase transitions and the corresponding responses in the internal quantities.

The Fourier transforms of the input drive signal and radiated output signal are shown in Figure 3.2. Two different "output" signals are represented: one derived from the equivalent circuit model end-to-end transfer function, the other from an actual measurement. The actual acoustic measurement comes from file C0425906.SAM, which was an 800-m deep transmission at station T50. Considerable low-frequency ambient noise is evident in the acoustic plot.

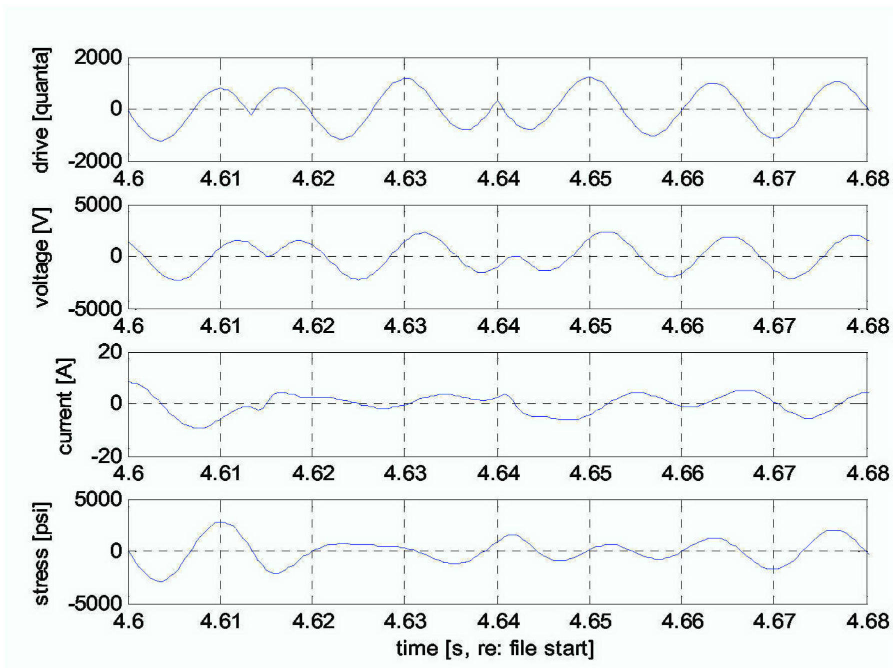

Figure 3.1. A plot of a short segment of M195.800 (top) followed by simulated responses in the stack voltage (second from top), auto-tuner current (third from top), and stack stress (bottom)

Figure 3.3 shows the three signals of Figure 3.2 after pulse compression. The spectral reshaping of the transducer broadens the simulated pulse. The in-water pulse has a similar trailing edge broadening.

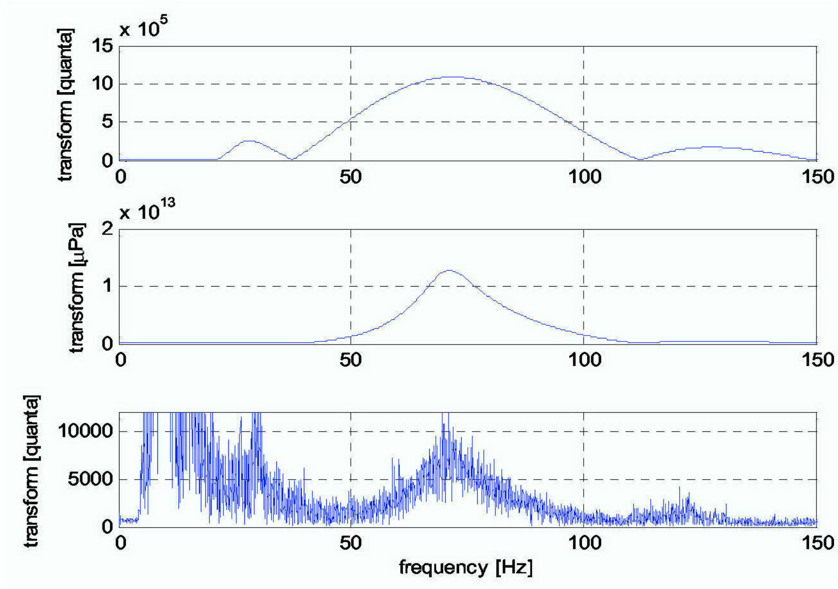

Figure 3.2. Fourier transform magnitudes: top, input drive signal; middle, simulated radiated output pressure using the 800Special model; bottom, the first M-sequence from C0425906.SAM acquired at station T50

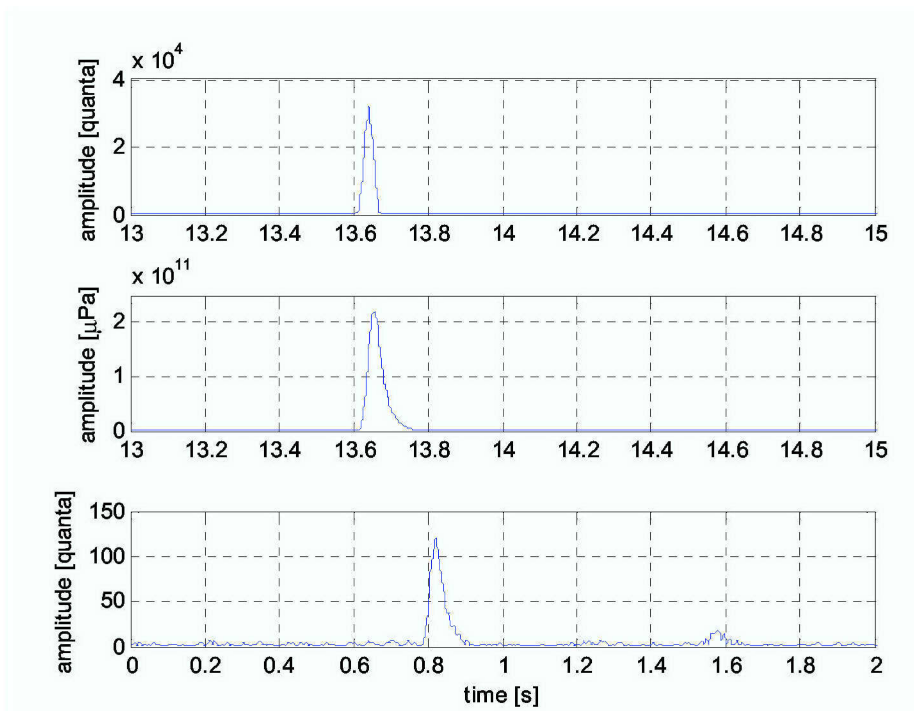

Figure 3.3. Processed M-sequences, using a simple MATLAB routine. Top: drive signal; middle: drive signal filtered by model impulse response; bottom: primary and secondary arrival, first M-sequence, C0425906.SAM, station T50. The time axes all have arbitrary references.

Prescription FMs

The prescription FM (PFM) signals were originally described by *Wang* (1994). These signals are optimum with respect to drive level under the constraint that their envelopes do not exceed a certain prescribed limit. The amplitude is tapered in order to achieve a target output spectrum. The sweep rate is varied so as to maximize the output level at every frequency, sweeping quickly through bands where less drive power is needed and more slowly through bands where more power is required.

In order to avoid transients in the output signal at junctions of discontinuous sweep rate, the full periodic PFM waveforms synthesized for LOAPEX consisted of an up sweep mirrored by a down sweep.

The PFM signals used during LOAPEX were scaled versions of those described in the *Cruise Plan* (*Mercer and Howe*, 2004). The scaling was necessary to achieve target radiated levels for both the M-sequences and the PFMs without resort to changing the power amplifier gain for each signal type.

The signal denoted PFM350B was the full power waveform used at 350 m and 500 m, and PFM800C was the full power waveform used at 800 m.

Table 3.3. PFM signal parameters

	PFM350B	**PFM800C**
filename	F195B.350	F195C.800
sweep [Hz]	32–92	45–105
duration [s]	30.0000	30.0000
max [quanta]	1263	945
min [quanta]	–1263	–945
rms [quanta]	712.24	583.46

The raw input files for the transmitter are in a custom format. These signals are also available in standard Microsoft ".wav" format files.

Table 3.4. PFM signal file names

original file	**.wav file**
F195B.350	F195B.350.wav
F195C.800	F195C.800.wav

Figure 3.4 shows the waveform F195C.800. The simulated internal auto-tuner current, stack voltage, and stack stress are shown in Figure 3.5. The simulated radiated

pressure waveform, spectrum, and sweep characteristics for this signal are shown in Fig. 3.6.

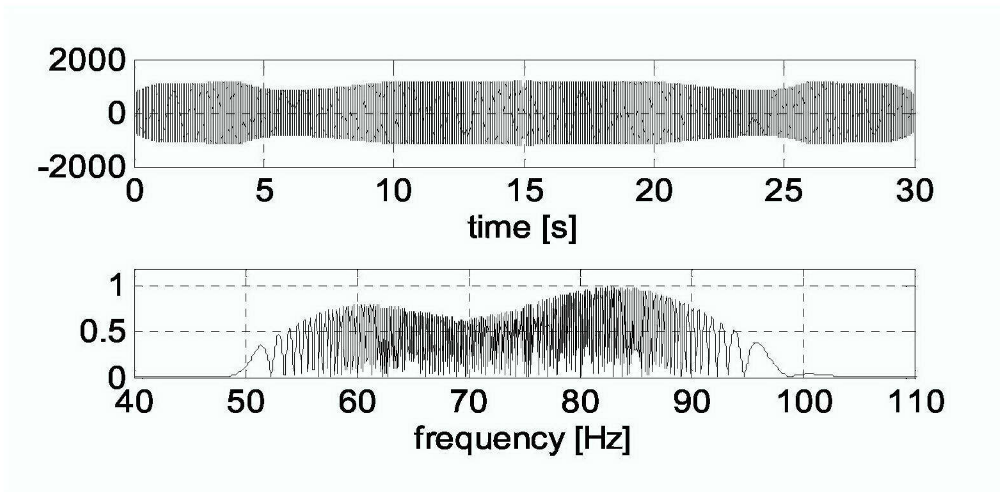

Figure 3.4. Time domain waveform (top) and magnitude Fourier transform (bottom), file F195C.800. The oscillations are too dense in the top panel to be seen individually.

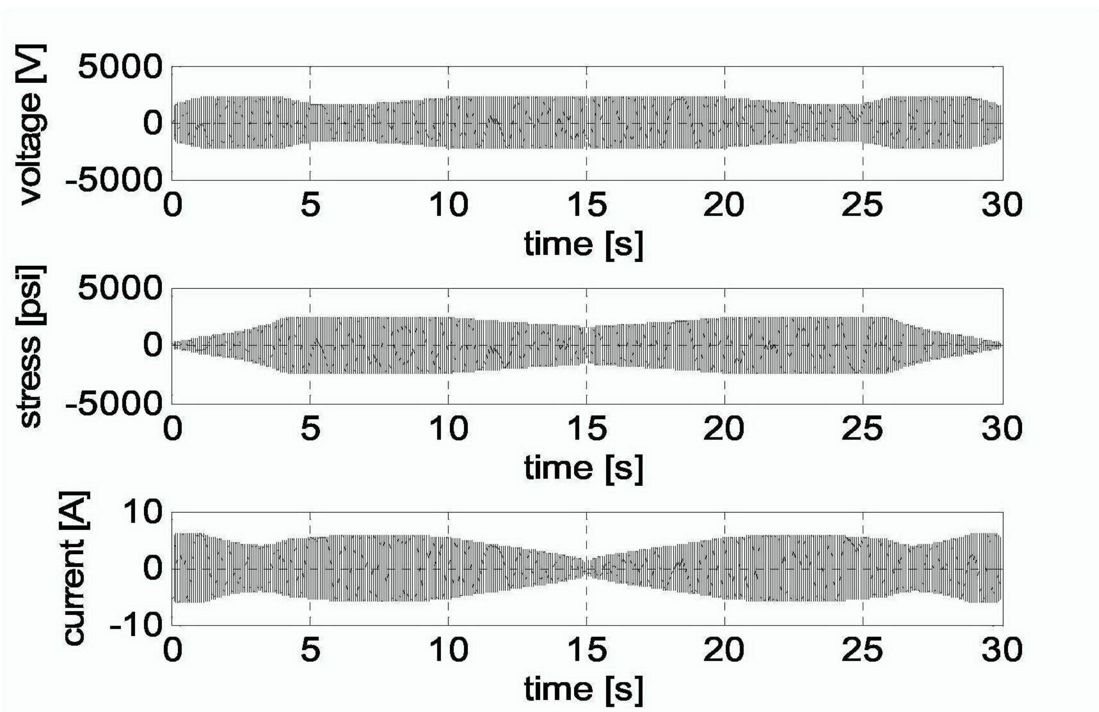

Figure 3.5. Simulated internal waveforms: stack voltage (top), stack stress (middle), tuner current (bottom). These simulations used the input file F195C.800 and the 800Special model.

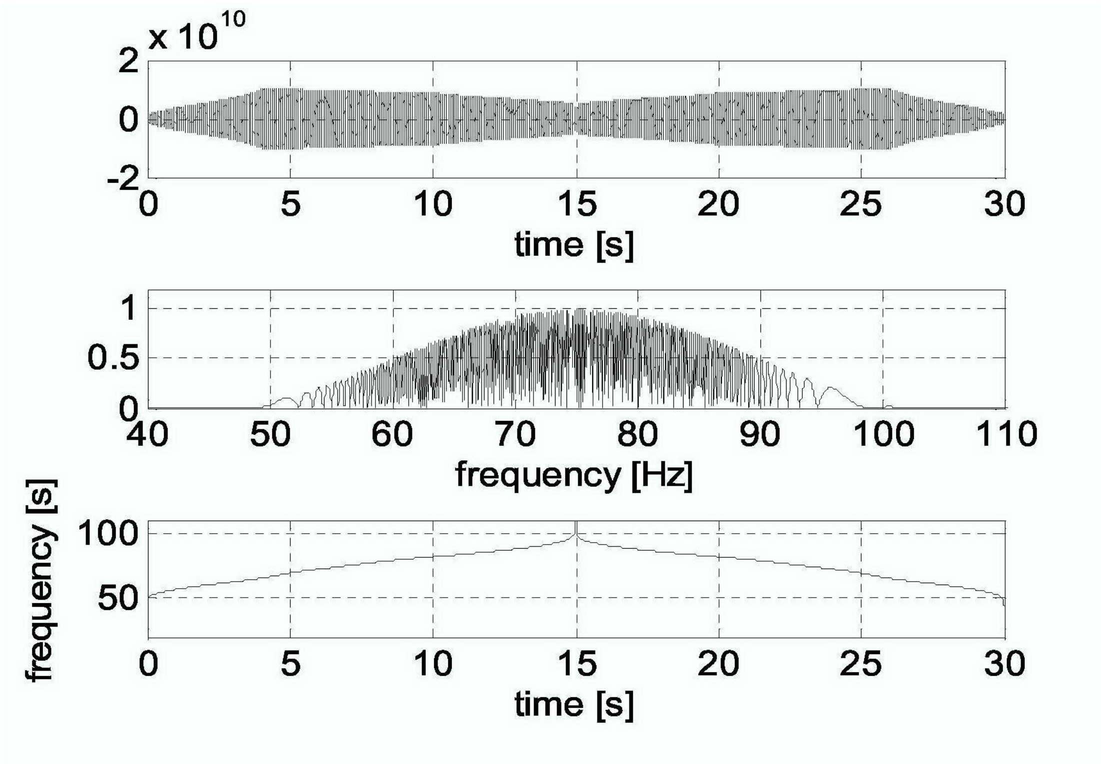

Figure 3.6. Simulated radiated pressure waveform (top), its Fourier transform (middle), and the corresponding sweep rate (bottom) for file F195C.800.

Pulse-compression with these signals can be achieved by cross-correlating the received acoustic signal with a replica of the transmitted signal. The transmitted signals have spectral characteristics that are significantly different from those of the transmitter input file signals: the transmitted signals produce negligible side lobes after pulse-compression, whereas the input signals yield significant side lobes.

"Transmitted" signals suitable for pulse-compression via cross-correlation are provided in two auxiliary file formats. These signals have been synthesized by filtering the input signal files detailed above with the system response. (As a consequence, the synthesized signals ought to have the source delay built into them.) The resulting signals are formally acoustic pressure quantities in units of micro Pascals corrected to a distance of 1 m from the source. They consist of double precision values at a sample rate of 2500 Hz. These files are described below.

Table 3.5. PFM signal filenames

signal	netCDF format	MATLAB format
PFM350B	PFM350.nc	PFM350.mat
PFM800C	PFM800.nc	PFM800.mat

The first format is the netCDF binary file format. This is an open-source format described at `http://www.unidata.ucar.edu/packages/netcdf`. A description of the contents of a single file are shown below:

Example: PFM350.nc (output from e.g., the `ncdump` program:)

```
netcdf PFM350 {
dimensions:
        index = 75000 ;
        singleton = 1 ;
variables:
        double sampling_rate(singleton) ;
                sampling_rate:units = "Hz" ;
        double signal(index) ;
                signal:units = "microPascals @ 1m" ;

// global attributes:
        :author = "Rex K. Andrew, APL, randrew@apl.washington.edu" ;
        :note = "Modeled in-water signal, 300mspecial@350m, 32-92Hz" ;
        :sponsor = "ONR code 321OA" ;
        :cruise = "LOAPEX 2004 (R/V Melville) (September - October 2004)" ;
}
```

The second format is a proprietary MATLAB binary file. Each file contains a single structure "PFM," whose contents are shown below.

Example: PFM800.mat

Contents:

```
               author: 'Rex K. Andrew, APL, randrew@apl.washington.edu'
              sponsor: 'ONR code 321OA'
               cruise: 'LOAPEX 2004 (R/V Melville) (September - October 2004)'
                 note: 'Modeled in-water signal, 800mspecial@800m, 45-105Hz'
   sampling_rate_units: 'Hz'
         sampling_rate: 2500
          signal_units: 'microPascals @ 1m'
               signal: [75000x1 double]
```

Examples of pulse compression are shown in Figure 3.7. These results were computed using PFM800C. The LOAPEX data was from the file C0425915.SAM, a transmission at station T50 at 800 m, and used the first PFM waveform.

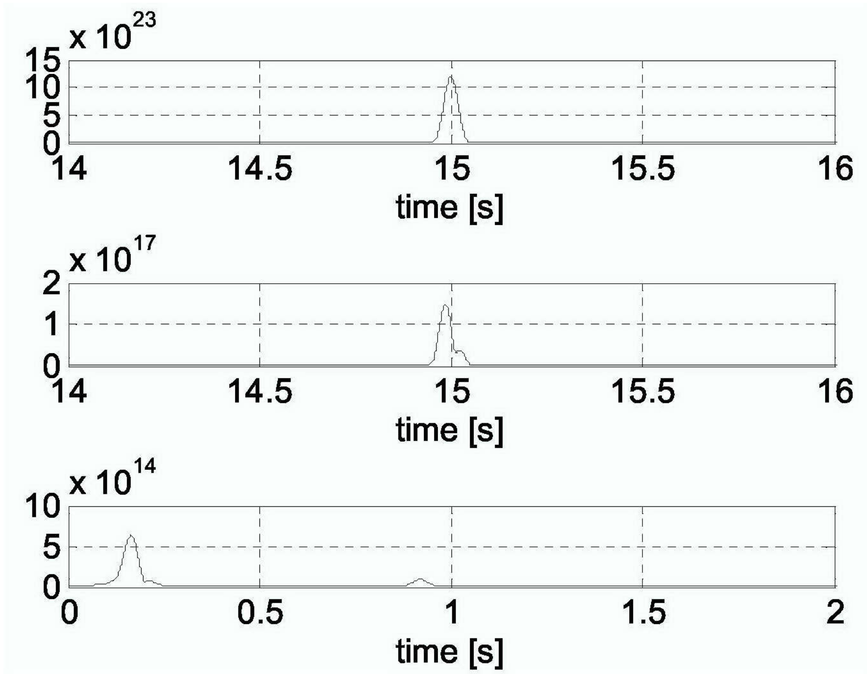

Figure 3.7. Pulse compressed waveforms. Top: PFM800C pulse compressed with itself. Middle: Waveform from F195C.800 pulse compressed against PFM800C. Note that the main peak is arriving early. This follows because the waveform PFM800C has passed through the simulator: it has zero delay with respect to itself (top panel) but is later than the input signal, hence the input signal appears to arrive early (middle panel). Bottom: primary and secondary arrivals from the first PFM from file C0425915.SAM compressed against PFM800C. It is currently not known why the primary pulse appears to have a small trailing pulse similar to the response in the middle panel.

Pentalines

These were not true Pentaline signals, but rather 3-digit M-sequences. An example spectrum is shown in Figure 3.8. Separate files were built for each depth to optimize the radiated source level. The parameters for these signals are shown in Table 3.6.

Table 3.6. Pentaline signal parameters

	PL800	PL350D	PL350E
filename	PENTA.800	PENTA.500	PENTA.350
law [octal]	5	5	5
Digits	3	3	3
carrier [Hz]	75	68	68
cycles per digit	5	5	5
modulation angle [deg]	69.3	69.3	69.3
duration [seconds]	0.200s	0.2206s	0.2206s
initial digits	0 1 0	0 1 0	0 1 0
max [quanta]	1179*	926	1235
min [quanta]	–1206*	–953	–1271
rms [quanta]	739.35*	581.57	775.58

*Used a PA drive dial setting of 270 vice 399.

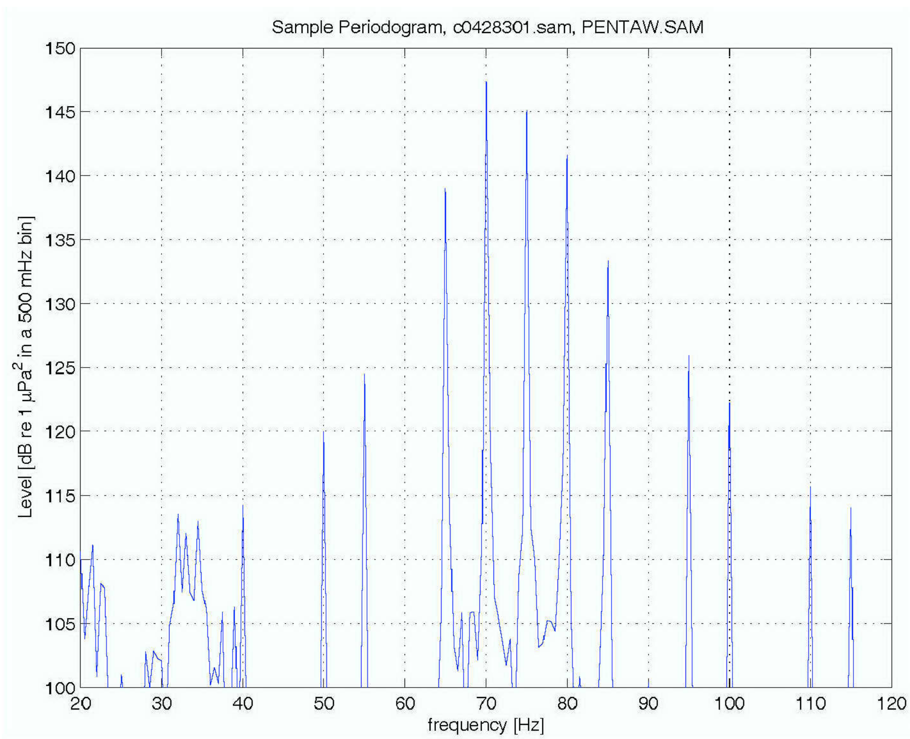

Figure 3.8. Example spectrum of Pentaline signal

Engineering Transmissions

There were two signals used for local engineering measurements, M75(175) and M68. These signals are both M-sequences. The signal M68 was the low-level waveform used at 500 m and 350 m, and M75(175) was the low-level waveform used at 800 m. They were originally designed to radiate levels 20 dB lower than that of their full-power counterparts, but no attempt was made during the cruise to maintain these exact relationships, particularly as the 68-Hz M-sequence measurements processed much faster than the 68.2-Hz transmissions. Their parameters are shown in Table 3.7.

Table 3.7. M-sequence engineering transmission parameters

	M68	**M75(175)**
filename	M175.350	M175.800
law [octal]	2033	2033
digits	1023	1023
carrier [Hz]	68	75
cycles per digit	2	2
modulation angle [deg]	88.209215	88.209215
duration	30.0882	27.2800
initial digits	00 00 00 00 01	00 00 00 00 01
max [quanta]	142	124
min [quanta]	–142	–124
rms [quanta]	83.6	72.38

The raw input files for the transmitter are in a custom format. These signals are also available in standard Microsoft ".wav" format files as follows:

Table 3.8. M-sequence engineering transmission filenames

original file	**.wav file**
M175.350	M175.350.wav
M175.800	M175.800.wav

`CRON`

Consistent transmission timing was accomplished using a GPS receiver and custom GPS interface and scheduler programs on the DOS transmitter computer. The

GPS interface was a terminate and stay resident (TSR) program that collected GPS receiver time messages from the serial port, reformatted the messages into time stamps, and delivered the time stamps every second to client programs. The main client was the scheduler, which was modeled after the UNIX program CRON and therefore was also called `CRON`. The scheduler built a list of tasks at initialization and then ran continuously, reading the GPS interface every second and comparing that time against the start time of each task in the list. When a task start time became due, the scheduler called the corresponding DOS batch program, which orchestrated the actual launch of the transmission and any post-processing and data file management.

The notions of "transmission start time" and "mark time" deserve a brief discussion. Under the fiction that the transmitted signal is a very short timing pulse, the "mark time" would be the onset of the pulse at the D/A output. In reality, of course, we transmit extended waveforms, and the mark time corresponds to the beginning of the waveform. The greater part of the DOS computer custom hardware and software is devoted to delivering signals to the D/A such that the mark time is within a few microseconds of the transition between appropriate seconds on the GPS 1-Hz clock.

For the purposes of this report, the "transmission start time" should be interpreted as the mark time, defined above. Some confusion can arise, however, because the signal does not really come out of the D/A at the mark time: prior to the mark time, the transmitter actually emits a ramp signal. The ramp signal consists of at most 1 s of silence, 300 s of gain-stepped waveform, and one full power period of the waveform. The duration of the ramp is 300 s plus the period of the waveform, rounded up to the nearest whole second. The length of the prefixed silence is such that the ramp signal ends precisely at the mark time. All long-range transmissions included a ramp.

The essential components of the timing problem are shown in Fig. 3.9. For clarity a simple transmission is shown, consisting of a ramp, one period of full strength signal waveform (A), and the principal scientific transmission, which is represented by two signal periods (B and C).

The impulse response of a waveguide will contain early to late arrivals. The travel time of the latest (i.e., slowest) arrival is denoted τR. The travel time of this slowest field is the integral of the slowness at the sound speed axis over the geodesic path from transmitter to receiver. LOAPEX calculations approximated this integral using September Levitus sound speed profiles picked every 1 km along the track, generating values of slowness from interpolations at the sound speed minima.

For visualization purposes it is desirable to offset the transmission start time so that after pulse compression at the receiver, the entire arrival pattern (from early to late arrivals) occurs within the processed data vector, as opposed to straddling the ends of the vector, i.e., with some of the response at the beginning and the balance at the end. To facilitate this an offset δ was introduced to provide a delay from the end of the final arrival for the first period in the primary transmission (period B in the figure) to the end of the acquisition window for that period. The entire arrival pattern should then conclude

δ seconds before the end of the data vector. This offset δ was 4.0 s.

For LOAPEX, the receiver turn-on times were fixed, and therefore the mark times were calculated as

$$TTX = TRX - \tau R - \delta,$$

where TRX is the start time of a reception at the DVLA, which is known.

All transmission start times listed in the summaries correspond to the mark times and differ slightly from the times listed in the initial cruise plan.

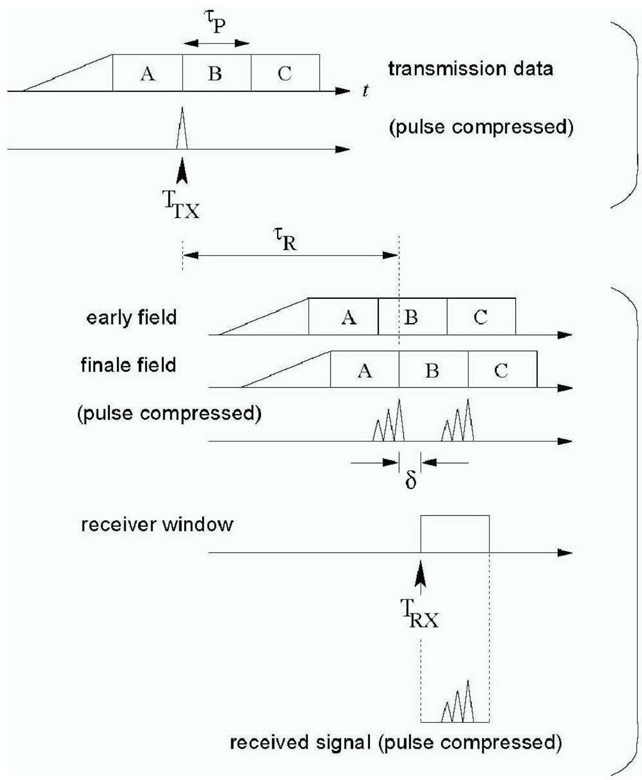

Figure 3.9. The timing problem in LOAPEX transmissions. The transmission is shown at top, which consists of a ramp followed by one period of full strength transmission ("A"), followed by the principal signal consisting of "B" and "C." The time of the transition from A to B is the "mark time" or the "transmission time" TTX. Timing considerations at the receiver site are shown at the bottom.

Standard 12-hour Schedule

The transmission schedule adhered closely to that described in the cruise plan. The 80-min transmissions targeted the DVLA receptions at 0500 and 1700 UTC. A 20-min PFM transmission always preceded the 80-min transmission. When the Pentaline

transmissions were added (station Kauai only), they were included in the two transmissions prior to the PFM.

Pressurization and Impedance Tests

At each station the pressurization of the source was monitored by interrogating the source before and during pressurization. The primary measurement involved injecting a low level wideband signal into the cable, and measuring the current response. From these two waveforms, the complex admittance and impedance curves (as a function of frequency) can be determined. These impedance curves, denoted here simply as "loop plots," generally show the evolution of the transducer resonance characteristics from liquid-filled liquid-loaded prior to pressurization to gas-filled liquid-loaded after pressurization. Each measurement transmits four M-sequences, comprising roughly 120 s; post-processing utilizes the second waveform.

An auxiliary measurement, sometimes available, is the radiated source level, as measured on the monitor hydrophone and corrected for range.

When source pressurization proceeds routinely it is thought to be sufficient to make an impedance measurement roughly every 5–10 min. The source is generally considered fully pressurized when the loop plots stop changing from one measurement to the next. Based on original experience, pressurization was expected to take 15–30 min, depending on depth. Experienced gained on the 2004 *New Horizon* cruise suggested the pressurization would take longer than this, but less than one hour. At the first couple of stations, pressurizing at 800 m seemed to take only 30 min; however, at later stations, this time increased to more than 60 min.

It also appeared to be necessary to "repressurize" at several stations. This was indicated when the loop plots from hourly transmissions began to change. A short repressurization effort generally returned the performance of the system back to nominal.

Fig. 3.10 shows a LOAPEX loop plot taken at 350 m. The loop plots provided in 1993 by Alliant Techsystems for the HX554 transducers at acceptance test time typically show a single loop. Figure 3.10 has this single loop appearance. The size of the loop, its location in complex impedance or admittance space, and the location of the resonance frequency on the loop all varied with depth, but there was only one loop in the Alliant Techsystems measurements. Based on Fig. 3.10, the acoustic performance of the source during LOAPEX at 350 m was similar to that at unit delivery.

However, the situation was much more complex for deeper operations. The loop plots at 800 m invariably contained two resonance loops, instead of one. Fig. 3.11 is an example. We first observed this behavior during the *New Horizon* cruise.

At station T1600 we conducted a multi-depth pressurization experiment. We pressurized the source at 900 m, and then raised it in 100-m increments to 400 m, followed by one final 50-m increment to 350 m. At each depth we conducted an impedance measurement. Initially, at 900m, we observed two distinct resonance loops,

which was typical from the *New Horizon* cruise for deeper source responses in a "fully pressurized state." At each successive depth we observed the higher frequency loop merging into the lower frequency loop. At 500 m the higher frequency loop persisted only as a kink in a single large loop. At 400 m and at 350 m, our loop plots contain only a single loop, very similar to those produced by Alliant Techsystems in 1993 at unit delivery.

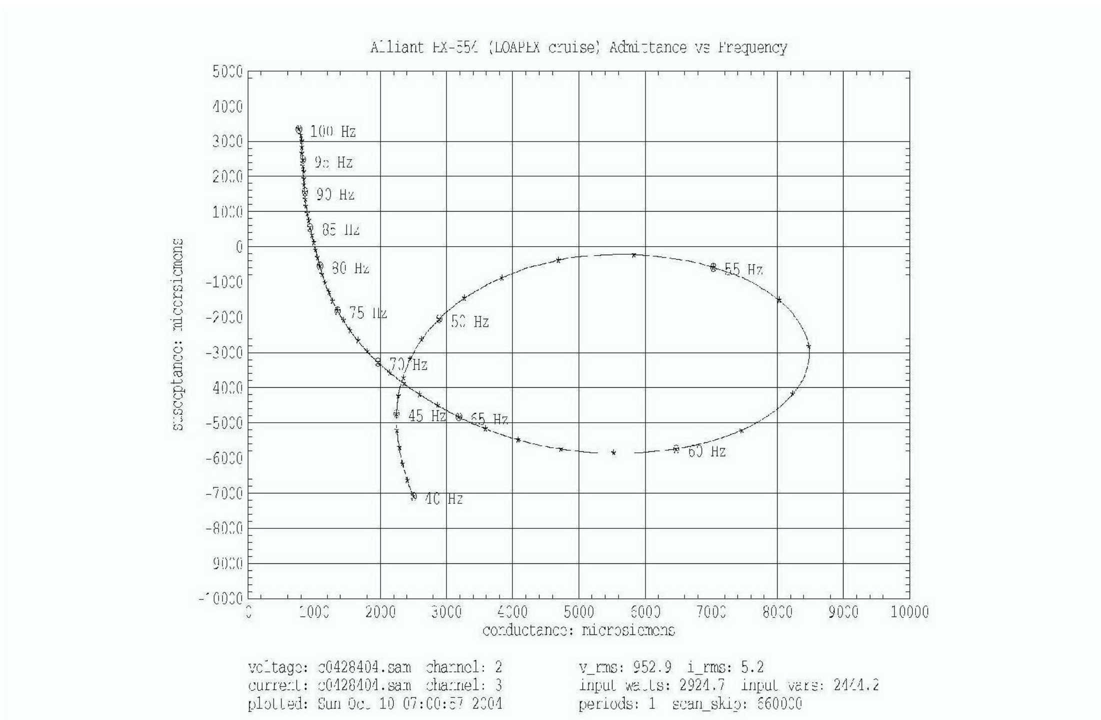

Figure 3.10. Loop plot for 350 m

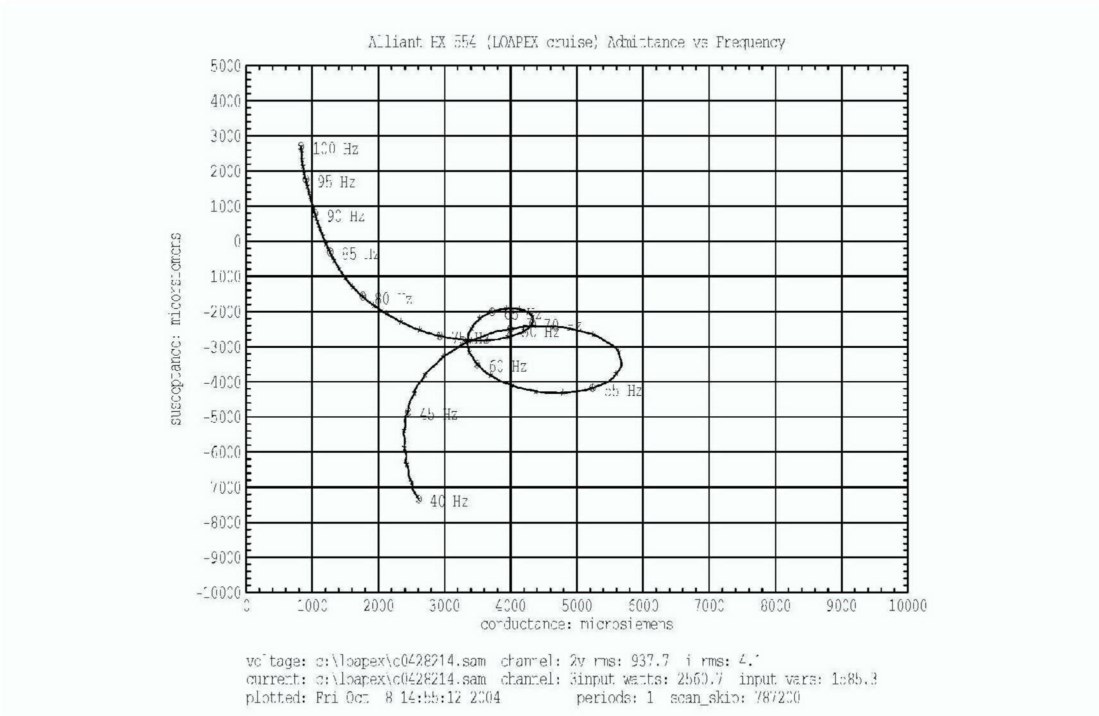

Figure 3.11. Example loop plot for 800 m

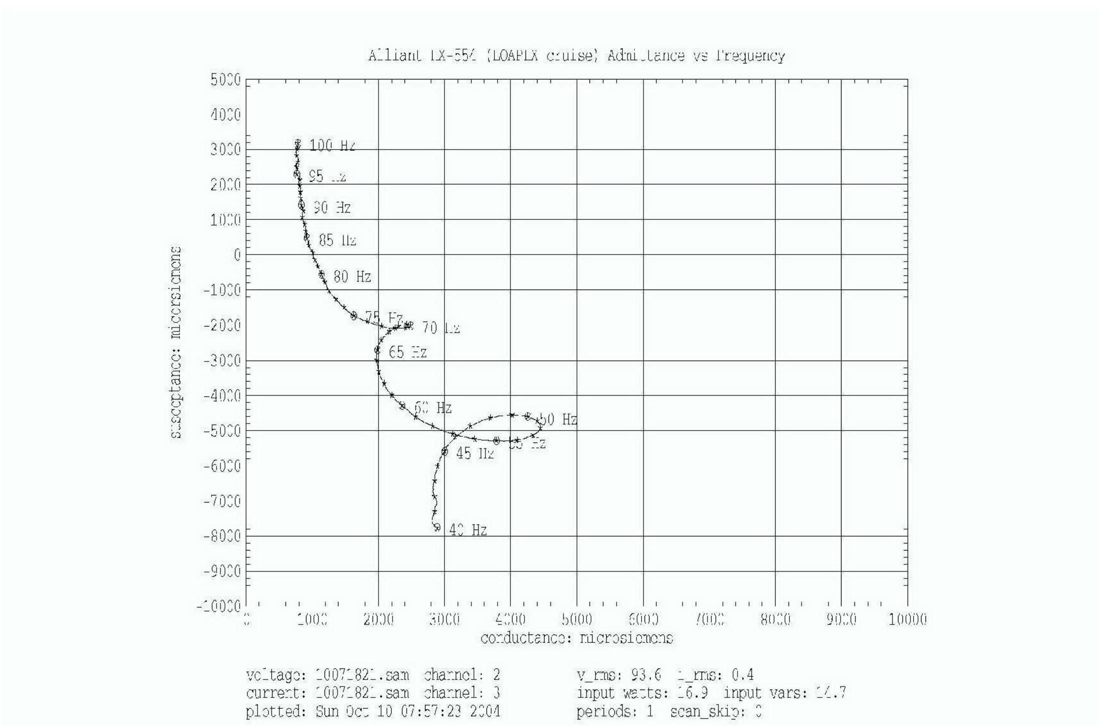

Figure 3.12. Loop plot taken at 800 m during pressurization; interior cavity partially filled

As mentioned above, during the early part of the cruise, we made an impedance measurement roughly every 5–10 min during pressurization. Our concern about anomalous source performance grew throughout the experiment so that by the Kauai station, we were making impedance measurements one after the other as rapidly as possible to watch the evolution of the resonance curve(s). The following is a description of this evolution as observed at the Kauai station, at a deployment depth of 800 m.

Initially, once the source was deployed to depth, and prior to pressurization, impedance measurements indicated a single resonance. Once pressurization commenced a second, much smaller resonance loop would form at a higher frequency. As pressurization continued the lower loop would gradually increase in frequency, and the higher loop would decrease in frequency. Because this investigation utilized a source deployment at 800 m, the loop plot structure was expected to stop changing with the two loops remaining distinct, as in Fig. 3.11, and this is indeed what was observed.

If this investigation could have been carried out for a deployment at 350 m, one would expect the two loops to continue to move toward each other and merge into a single loop, as in Fig. 3.10. Unfortunately, no such measurement was made.

Although the evolution of the resonance loop plots at the Kauai station bears a clear resemblance to the evolution of the loop plots during the multi-depth pressurization exercise conducted at station T1600, the full ramifications of this similarity remain to be understood. Alliant Techsystems did not provide us with measurements of the electrical response of the device when it is only partially pressurized, nor do we have a model of this situation. We do not have their explanation for the behavior of the loop plots as pressurization proceeds from initial to final stages.

An explanation can be advanced to explain this behavior. Initially, once the source is deployed to depth, and prior to pressurization, the internal cavity is essentially fully liquid-filled. Impedance measurements at this point would indicate a single resonance loop, consistent with the presence of a single-fluid volume inside the source.

Once pressurization commences a volume of gas slowly builds in the interior, displacing the liquid. Impedance measurements during this stage would show two resonance loops: two loops are consistent with the presence of two considerably dissimilar fluids inside the source. The larger, lower frequency resonance characterizes the liquid volume, and the new, higher frequency resonance the gas volume. As the liquid is displaced, the liquid volume in the interior decreases, and the fundamental mode resonance frequency associated with the liquid phase increases. At the same time, as the small gas volume expands, the fundamental mode associated with it decreases. When the gas has displaced all the liquid, only a single resonance mode would remain, due to the gas-filled cavity.

Signal Monitoring

The signals transmitted from the HX554 source were acquired by a monitor hydrophone suspended on the hydro wire from the ship's squirt boom. The hydrophone was positioned at a nominal depth of 575 m. The distance aft from the wire to the source cable during deployment (i.e., with the A-frame all the way out) was approximately 28.5 m.

The hydrophone used was the ITC 8211 s/n 001. The signal was routed into the winch van (electronics partition) and into the "Nimbin" unit UW s/n 826682. The signal cable was connected to channel 2 of the preamplifier module, labeled ITC/B&K HYPH 30 dB. Channel 2 actually provides 20 dB gain over the band of interest and is essentially flat. The preamplifier output was routed through a two-stage Krohn-Hite filter s/n 1527. The first stage was configured as a high-pass filter with corner at 10 Hz for the early part of the cruise, and later at 20 Hz, in order to reduce the fundamental blade rate noise contribution from the ship's thrusters. The second stage was configured as a low-pass filter with corner at 1000 Hz. The output was then routed to the "bare" D/A input connector J35 labeled "HY-A" on the back of the "VLA" telemetry chassis.

The actual slant range from HX554 to the hydrophone was computed from the acoustic signals using pulse compression. The slant range was estimated at about 225 m for the 800-m source deployment, 80 m for the 500-m source deployment, and again 225 m for the 350-m source deployment. These estimates used M-sequences and the program `proc` (various versions). Range estimates using the PFM signal and MATLAB routines were about 10% higher.

4. Source Motion

Knowledge of the absolute source position is required for the tomographic application. Knowledge of the relative source motion, on time scales of 10 s to 80 min and spatial scales of 2 m to 5 m (1/10th to ¼ wavelength at 75 Hz) is required for the acoustic propagation aspects of the experiment, especially the temporal and spatial coherence estimates. Several measurement systems were used to provide data for estimating source position as a function of time (Figure 4.1):

- C-Nav GPS – A-frame position where the source cable enters the water
- Acoustic Doppler current profiler (ADCP) measuring low-frequency currents to 800 m
- Acoustic tracking of the source relative to a bottom transponder
- MicroCat pressure and temperature at the source, to provide source depth
- S4 current meter to provide relative current between the source and the water

The first two, GPS and ADCP, are used as the forcing for a cable dynamics model (J. Gobat, APL-UW) to estimate source position on a second-by-second basis. The balance of the measurements are used partly to tune the model (primarily horizontal drag coefficient for the cable) and partly to verify the model. Some of the comparisons between the different data are summarized in the next paragraph, before presenting the data in more detail in the following sections.

Measurements made in San Diego while dockside confirmed that the C-Nav GPS system is capable of decimeter accuracy in position. The vertical source motion predicted by a simple spring model (J. Colosi) driven by the C-Nav vertical motion shows remarkable agreement with MicroCat depth measurements, with the source moving 40% less than the A-frame because of cable elasticity and drag. The horizontal motion of the source in the direction of the VLAs was measured directly with the long-baseline acoustic navigation system; resulting estimates of source position are in excellent agreement with the C-Nav data and cable dynamics predictions based on C-Nav data. The horizontal velocity of the source relative to the water measured by the S4 current meter agrees with the C-Nav GPS derived velocity on time scales of minutes to one hour, and with ADCP data on one-hour and longer time scales. The good agreement between the different data sets leads us to fully expect absolute source position accuracy better than 5 m to be easily obtained, better than 2 m with the model, and possibly, better than 1 m if all data were rigorously combined.

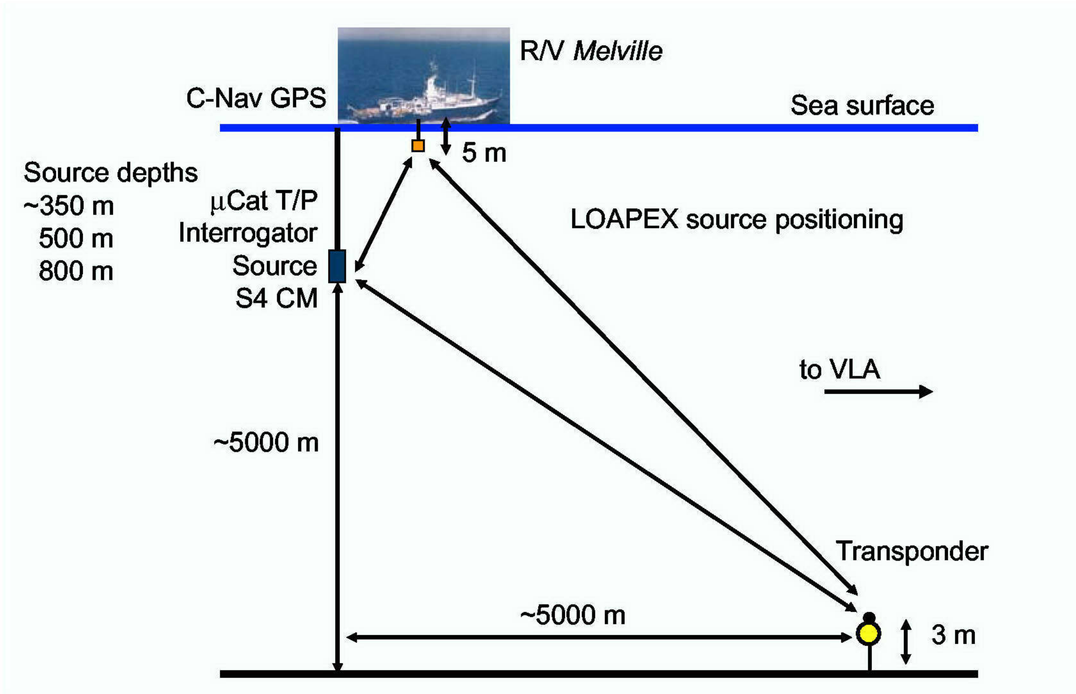

Figure 4.1. LOAPEX source tracking

C-Nav GPS Data

The C-Nav GPS system provides the time-dependent (one sample per second) position of the source sheave in the stern A-frame (Figure 4.2)—a first and most reliable and consistent estimate of the horizontal position and vertical heave of the source. The dual frequency system obtains real-time corrections via Inmarsat satellite communications; the corrections for GPS satellite orbits and clocks and the troposphere are determined using data from the JPL-operated Global GPS Network (GGN) in the Real-Time GYPSY (RTG) software package and are globally uniform and applicable worldwide. The estimated accuracy is decimeter. While on station the ship's navigation/DP system was set up to keep the center of the deployed stern A-frame/C-Nav antenna at the station location specified in Table 4.1 (identical positions as Table 2 in the *Cruise Plan*). Note that the ranges to the DVLA for Stations T500 and T1000 are actually 490 and 990 km, respectively. This was to avoid the SPICE moorings at the ranges of 500 and 1000 km.

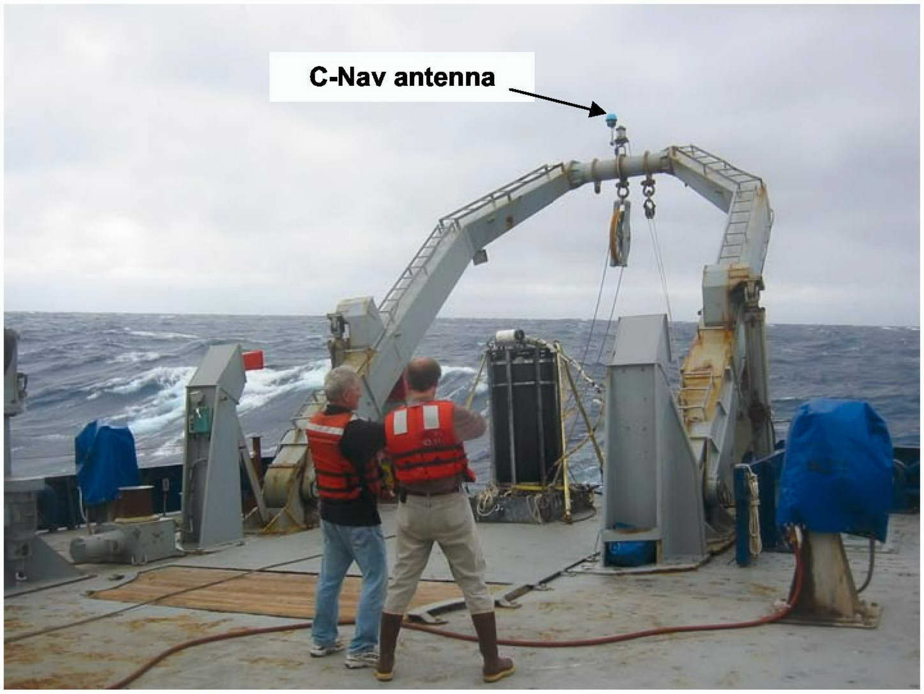

Figure 4.2. The blue C-Nav antenna is next to the navigation light at the center of the A-frame.

Dockside comparisons of the C-Nav system with the other shipboard GPS systems (Trimble Tasman P-code and Furuno GP-90 C/A code) were made in San Diego and Honolulu. Plots for the San Diego data are given in Figures 4.3–4.5 and the statistics in Table 4.2 (calculated after the medians were removed). Approximately 9.5 hr of data are plotted in these figures. The C-Nav data are uniformly smooth and the variability as reflected in the statistics was about one order of magnitude lower than for the other two systems; the latter two had comparable statistics. Both the P-code and the C/A code data showed significant jumps and variability. The small motion of the ship at the dock is also included in the statistics. The low-frequency variability in the C-Nav vertical motion corresponds to the changing of the tide. Tide tables predicted a 1.12-m peak-to-peak change between a low at 08:38 and a high at 15:28 UTC (year days 253.36 and 253.64), almost exactly what was measured by the C-Nav system (Figure 4.5).

Table 4.1. LOAPEX Station coordinates, with range to the deep VLA.

Station	Latitude N (decimal degrees)	Longitude E (decimal degrees)	Latitude N (deg min)	Longitude E (deg min)	VLA (km)
T50	33.513590	138.208350	33 30.8154	138 12.5010	50
T250	33.869780	140.322990	33 52.1868	140 19.3794	250
T500	34.248840	142.882500	34 14.9304	142 52.9500	490
T1000	34.864170	148.280130	34 51.8502	148 16.8078	990
T1600	35.285610	154.949970	35 17.1366	154 56.9982	1600
T2300	35.312730	162.647970	35 18.7638	162 38.8782	2300
T3200	34.631820	172.472870	34 37.9092	172 28.3722	3200
Kauai	22.553691	159.249620	22 33.2215	159 14.9772	2432

Table 4.2. Statistics from the three GPS systems, dockside in San Diego, 9 September 2004

	GPS System		
	C-Nav RTG-Dual	Trimble P code	GP-90 C/A code
	RMS (m)		
dx	0.11	0.66	0.88
dy	0.12	1.20	1.09
dz	0.40	2.36	2.10
	Peak-to-peak (m)		
dx	0.86	5.14	9.81
dy	0.97	6.67	8.33
dz	1.39	17.30	16.00

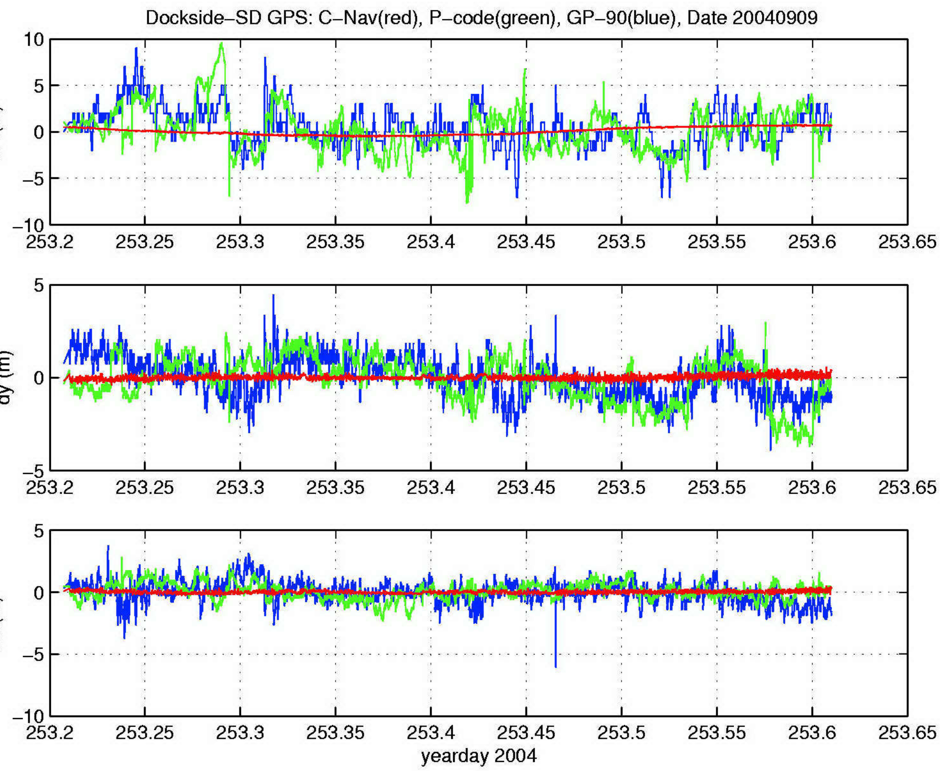

Figure 4.3. GPS data as a function of time while dockside in San Diego

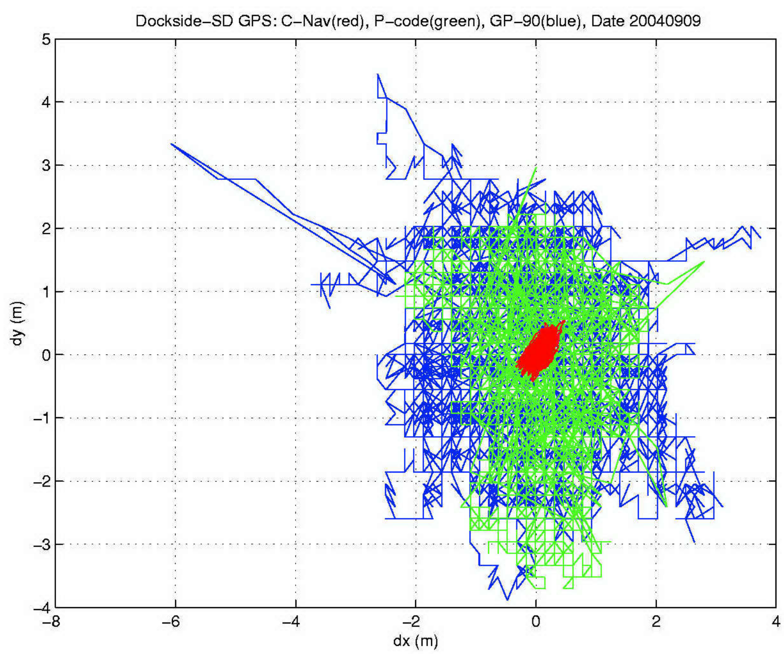

Figure 4.4. GPS horizontal data while dockside in San Diego

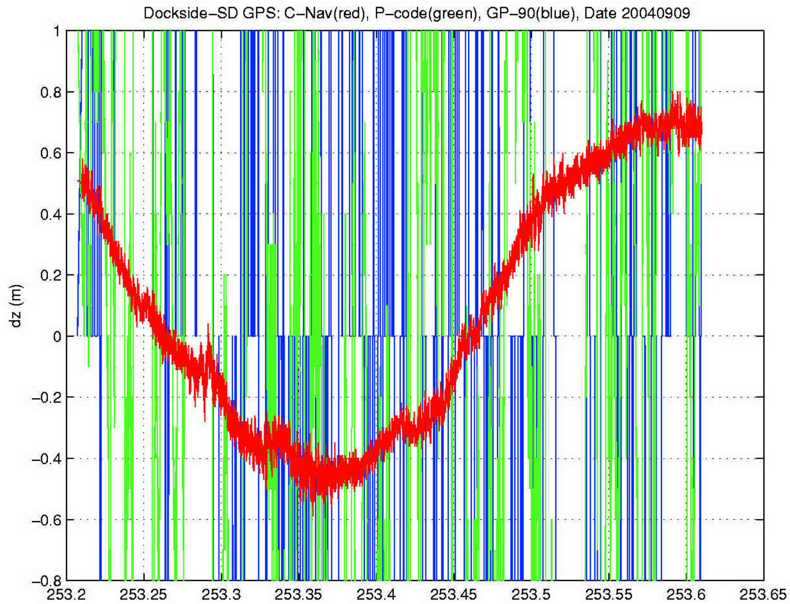

Figure 4.5. GPS vertical data while dockside, expanded to show the C-Nav tidal signal

During most of the cruise, the C-Nav data appear very clean. However, there were a few occasional, very short, noisy sections that will need editing. The vertical data showed long-term drift, as well as occasional step changes of several meters; the causes of these are unknown (raw binary data will be sent to the provider for review). At station T3200 the line of sight to the Inmarsat Americas satellite (for the real time correction data) was partially blocked by the ship's superstructure making the connection intermittent and causing the "age" of the correction to grow into the 100s of seconds, as compared to the usual 10 s.

Sample C-Nav data while at sea will be shown below in a following subsection in the context of comparisons with data collected with other systems.

MicroCat Depth and the Spring Model

The MicroCat was mounted approximately 25 m above the source package. Its sample rate was 15 s for T50–T2300, 11 s for T3200, and 5 s for Kauai. Initial comparisons between its measured depth versus time and the C-Nav vertical motion showed the amplitude of the former was only about 60% that of the latter. This led to considering the elasticity of the cable, and the vertical component of drag. J. Colosi constructed a simple spring model including these effects. The MicroCat depth, the C-Nav vertical heave, and the model predictions are plotted versus time in Figure 4.6. While the depth sample interval (here 11 s) is clearly longer than desired, the agreement is good. Note a small lag of about 1 s in the predicted source motion relative to C-Nav.

The effectiveness of the model is shown in the tighter correlation shown in Figure 4.7. For reference, the cable manufacturer estimates 0.0375% elongation per 1000 lb of load (0.2% or 1.6 m for 5,000 lb load at 800 m).

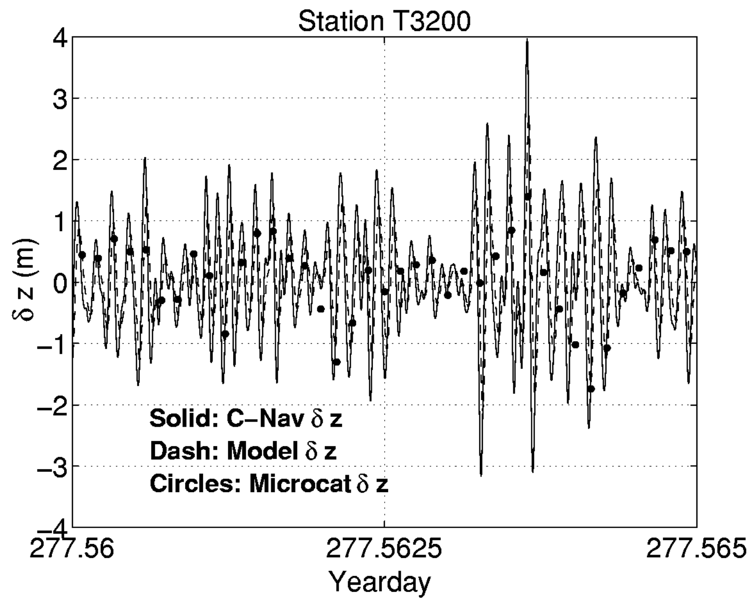

Figure 4.6. Comparing measured and predicted vertical source motion

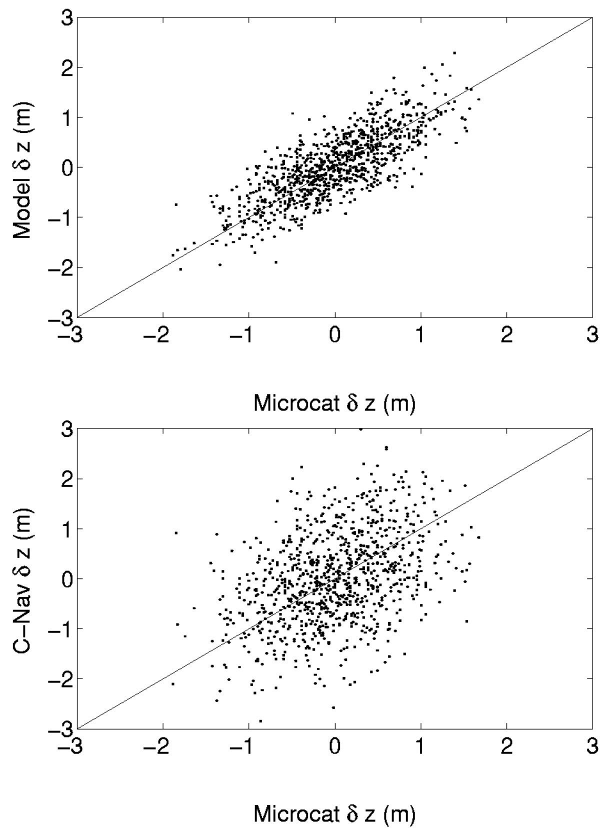

Figure 4.7. Modeled (using C-Nav) vs. measured (MicroCat) vertical source motion (top) and C-Nav vs. MicroCat vertical motion (bottom)

Acoustic Navigation

To provide a direct measure of horizontal source motion, we deployed a "poor man's" long baseline acoustic navigation system that measured motion relative to a single bottom acoustic transponder. A transponder was deployed 5 or 6 km short of each station along the path to the VLA (at the Kauai station, two transponders were deployed, one in the direction to the VLA and a second in an orthogonal direction). Because our purpose was discerning relative motion, the transponders were not surveyed, but rather nominal positions were determined from the drop position and depth. A "WHOI interrogator" was mounted 20 m above the source to measure the roundtrip travel time to the bottom transponder. This travel time and the nominal source/transponder geometry give the relative horizontal motion (with some small noise introduced by vertical heave); absolute position is obtained from the C-Nav GPS. The interrogator sample rate varied between 12 s and 24 s depending on the expected deployment duration; a second interrogator sampling at 3 s was used for T3200. For reference, the pendulum period is 57, 45, and 38 s at depths of 800, 500, and 350 m, respectively. Ship position was also monitored to

verify GPS performance using a Benthos DS-7000 deck box and transducer mounted at ~6 m depth on the starboard hydro-wire (with the source monitor hydrophone).

Table 4.3. Transponder information (preliminary)

Transponder	Latitude N (deg	min)	Longitude W (deg	min)	Depth m (C)
T50-5	33	30.1739	138	9.1720	5176
T250-5	33	51.7400	140	16.7100	
T500-5	34	14.4812	142	49.7375	5366
T1000-5a	34	51.4010	148	13.5529	5286
T1000-5b	34	51.5410	148	13.3590	5286
T1600-5	35	17.0151	154	53.7680	
T2300-6	35	18.8621	162	34.9580	5868
T3200-6	34	38.3490	172	24.4210	
Kauai-TX1	22	34.7358	159	12.5580	
Kauai-TX2	22	35.4390	159	16.6182	

The source motion relative to the bottom transponder in the direction of the VLA is determined from

$$\delta x = -\ C_0/\cos\theta_0 \times \delta t,$$

where C_0 is the nominal sound speed (1480 m s^{-1} was used here), θ_0 is the ray angle from the source to the transponder using the nominal geometry (~45°), and $\delta t = (tt - tt_0)/2$ is the perturbation travel time where tt and tt_0 are the measured and nominal round trip travel times.

The estimated δx and the C-Nav data from T3200 are plotted in Figure 4.8. During the time intervals shown (3.6 hr and 29 min), the source was at 500 m depth and the fast (3-s sample rate) interrogator was active. While the interrogator acoustic data is not noise free, the agreement with the C-Nav data is considered very good. Here the C-Nav east component is used for convenience because the path to the VLA is only a few degrees from east. Also, the ~1–2-m vertical source motion is ignored here. On the C-Nav data in the lower panel of the figure, one can see the small ship motion associated with ~10-s waves. Horizontal source motions are expected to have time scales of the pendulum period or longer. Differences between the C-Nav position and the acoustically determined position can be attributed to two things: there should be a phase lag of the

source relative to the ship motion because of drag (the cable dynamics model indicates this should be about the pendulum period), and, there should be some amplitude differences due to forcing/drag by water currents. The phase lag in the figure is about 43 s, close to the 45-s pendulum period.

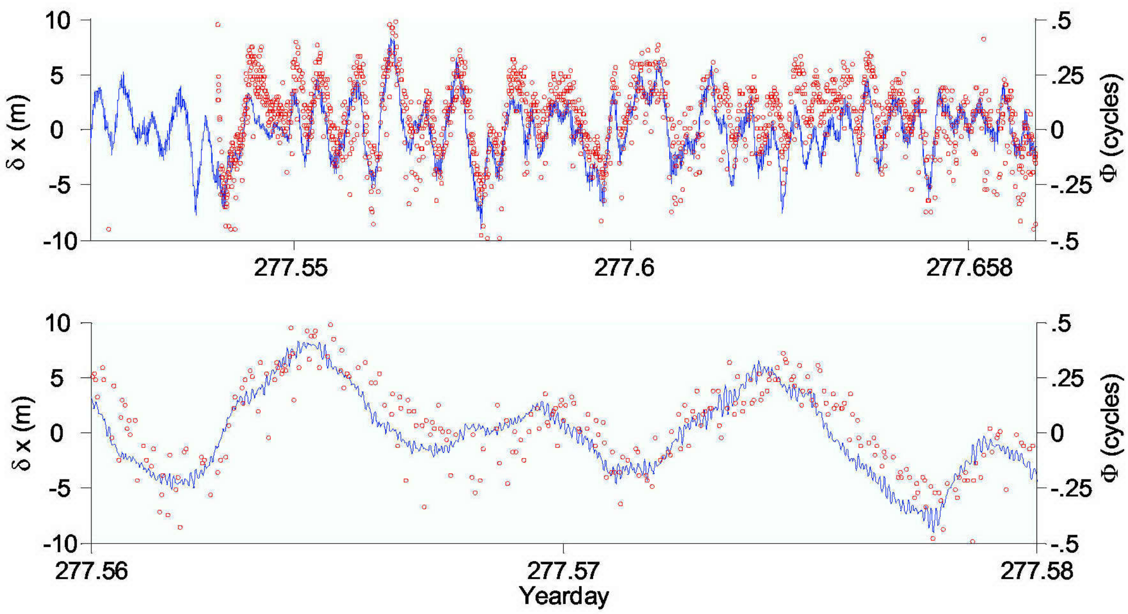

Figure 4.8. Horizontal source motion: direct acoustic measurement (red dots) and inferred from C-Nav GPS (blue line)

Cable Dynamics Model

The C-Nav data were used as input forcing to a cable dynamics program (J. Gobat and M. Zarnetske). The results are plotted in Figure 4.9. The source moves about the same in amplitude as the ship and there is a phase lag of the source relative to the ship of roughly 15 s, less than the pendulum period (45 s) and the C-Nav–interrogator difference (Figure 4.8). Understanding this difference, other phase lags introduced by the program, and adjusting the drag coefficients will be part of the on-going data analysis effort.

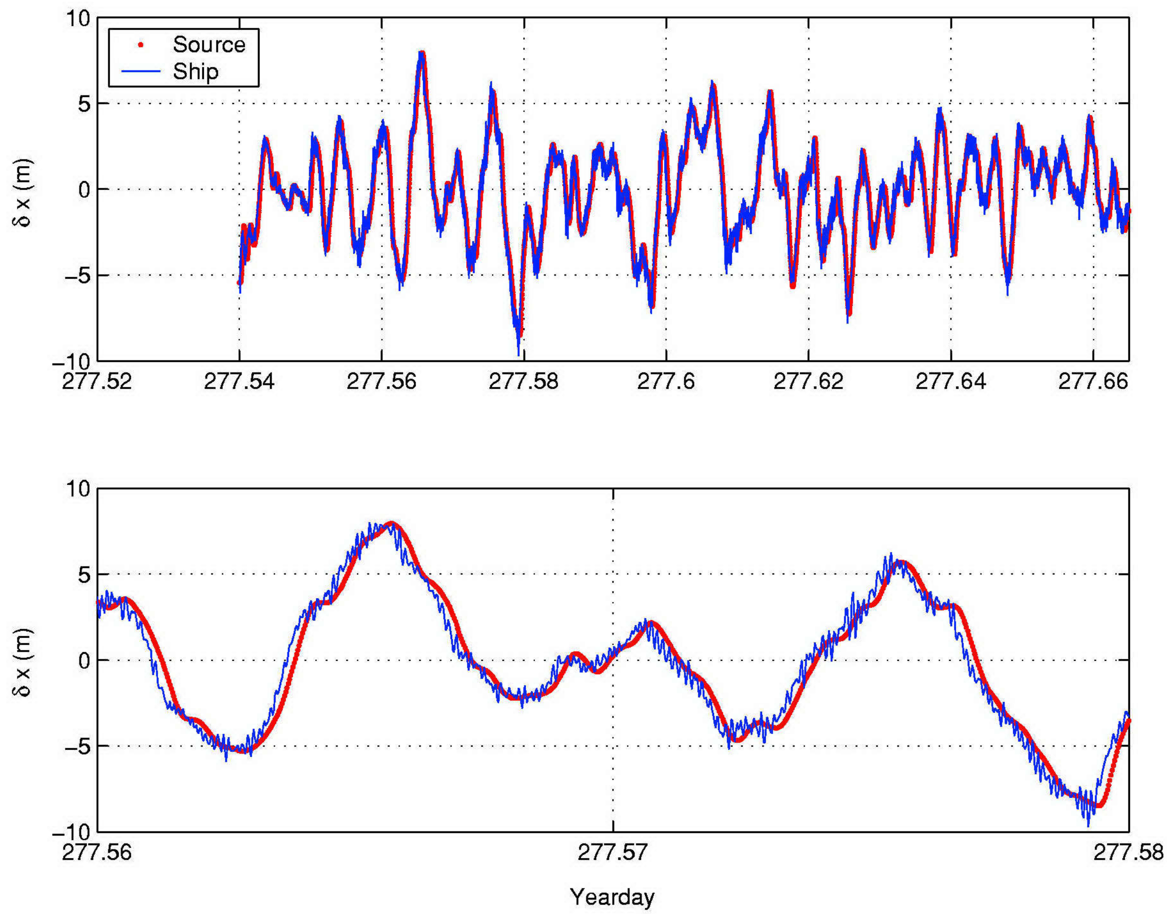

Figure 4.9. Horizontal source motion: cable dynamics program prediction (red) driven by ship motion (blue)

Current Measurements

Two current measurements were made. An S-4 current meter was suspended ~10 m below the source to measure relative velocity of water going by the source (sample interval 30 s), and the ship's 75-kHz Ocean Surveyor ADCP measured absolute velocity profiles to 800 m depth (1-min averages used here). Further, the velocity of the A-frame was estimated from the C-Nav position data. Figure 4.10 shows the data for T3200, 500 m source depth. In the top panel covering 18 hr, the long-term C-Nav velocity is zero because the ship was holding station. Over the same time scale the S-4 and ADCP (just the 500-m bin) velocity show close agreement, slowly varying by about 0.2 m s^{-1}. The bottom two panels of Figure 4.10 show expanded time scales (same as above figures, 3.6 hr and 29 min). For the fluctuation time scales in the lower two panels, about 8 min (corresponding to the ship slowly oscillating around the reference point), the S4 current is almost identical to the C-Nav velocity, implying that water currents are not affecting the source on time scales shorter than 3.6 hr. The small

difference between the S-4 and the ADCP data shown in the top panel of Figure 4.10 would indicate a small, slow effect of currents on the source.

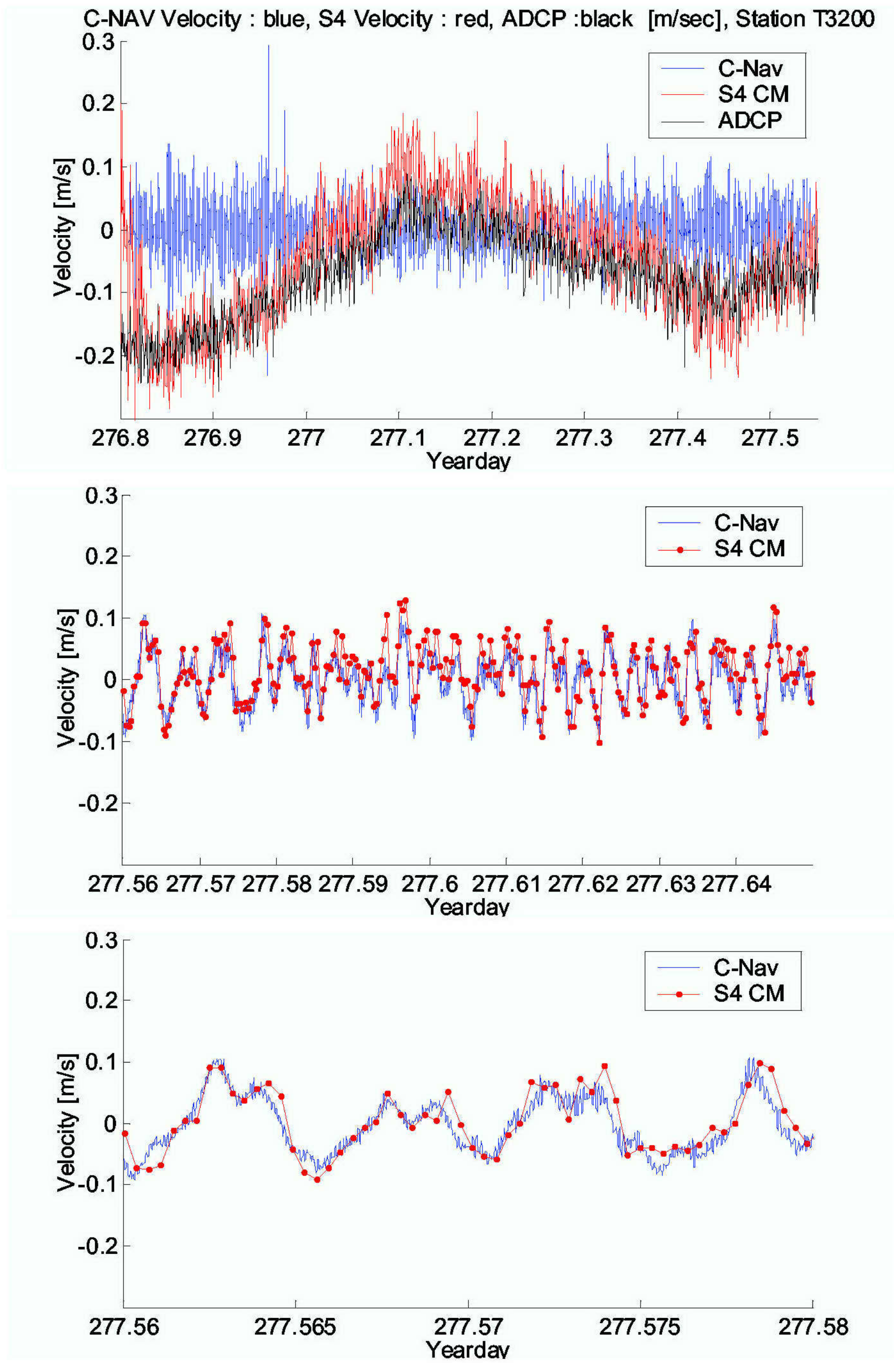

Figure 4.10. S-4 current meter, ADCP, and C-Nav velocities

5. Environmental Measurements

Observations of ocean sound speed structure were carried out using the SIO UCTD system, expendable bathythermographs (XBT)s, and the shipboard Seabird CTD. Other environmental observations included the deployment of two APL-UW Seagliders, ocean currents from the ship by 75-kHz ADCP (providing profiles from 750 m to 1000 m depth under ideal conditions), and ocean bathymetry from the ship's multibeam system.

The Underway CTD (UCTD)

A total of 177 UCTD casts were carried out using two probes (s/n 2006 and 2008). The UCTD data presented here should be considered preliminary as in some cases post-cruise calibrations can be applied. Two on-board calibrations with the Seabird CTD show that the vertical structures are correct but the absolute values of temperature and salinity may be incorrect at the order of 0.01°C and 0.06 psu, respectively. The main 2000-km transect lasted 10 days and consisted of 156 casts. UCTD data were collected during the east–west transect between source locations T50, T250, T500, T1000, T1600, and T2300, and ship speeds were typically 12–13 kt. One probe (s/n 2008) was lost between T500 and T1000. UCTD data were not collected between stations T2300 and T3200 so as not to risk loss of the last probe s/n 2006. Casts ranged in depth from a minimum of roughly 200 m to a maximum of 410 m, and were separated in time by 30–45 min giving a nominal 10–15-km range resolution.

Figure 5.1 shows the UCTD salinity measurements with isopyncal contours. Regions where isopyncals cross lines of constant salinity are regions of intrusive finestructure (spice). The mixed layer depth varied between 20 m and 40 m, with a strong gradient of density between 40 m and 50 m. The salinity minimum near the base of the mixed layer, which weakens to the west, is a well know feature of this region. A strong frontal feature is evident around 153°W. Weaker fronts are evident around 147°W and 141°W.

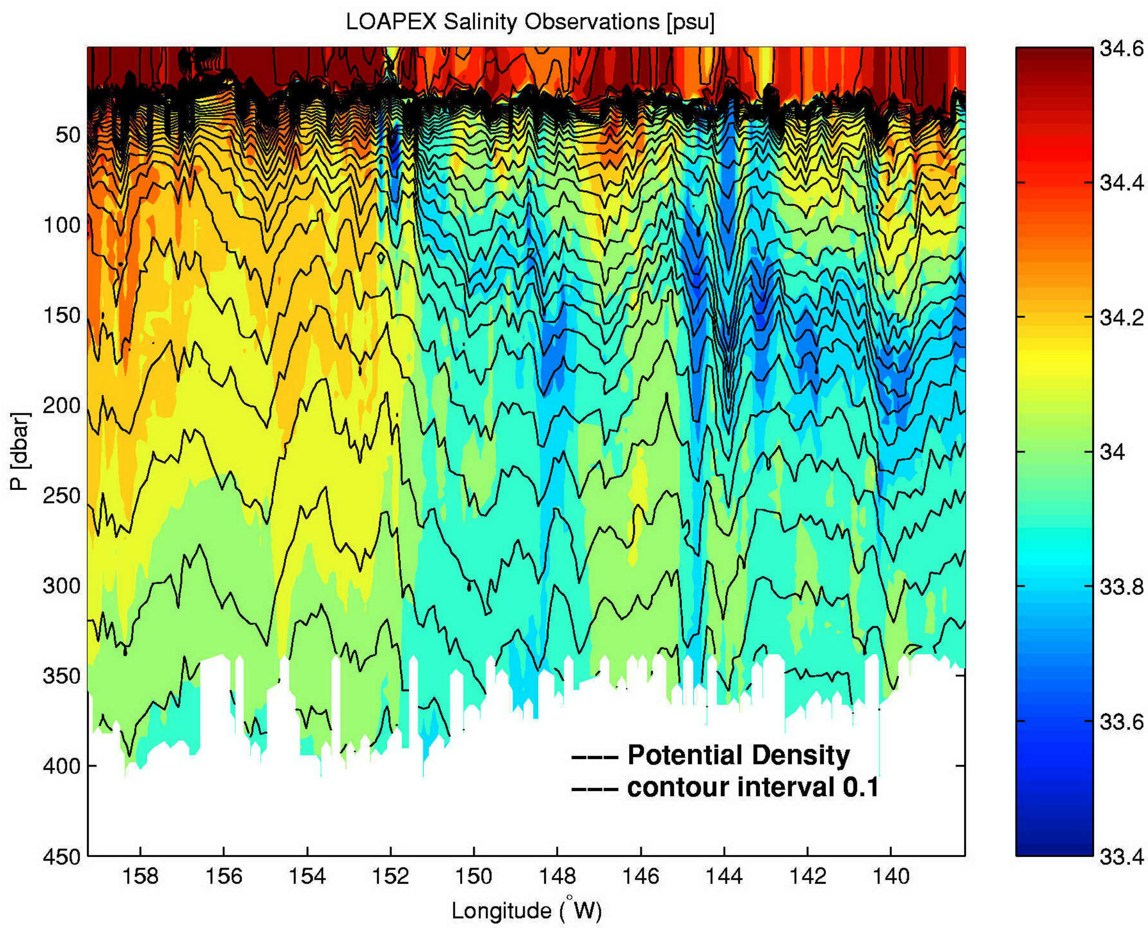

Figure 5.1. LOAPEX salinity section with potential density contours. Casts shallower than 340 m were filled in using cubic splines interpolation in the horizontal. Noisy salinity points were edited out and replaced using interpolation.

Figure 5.2 shows the UCTD sound speed section, which is of fundamental interest to the LOAPEX acoustic propagation studies. As in Figure 5.1, isopycnal contours are plotted over the section. Regions where the isopycnals cross contours of constant sound speed are where intrusive finestrucure (spice) exists. At fixed depth sound speed is seen to increase from the east to the west, evidence of some range dependence in the background sound speed profile.

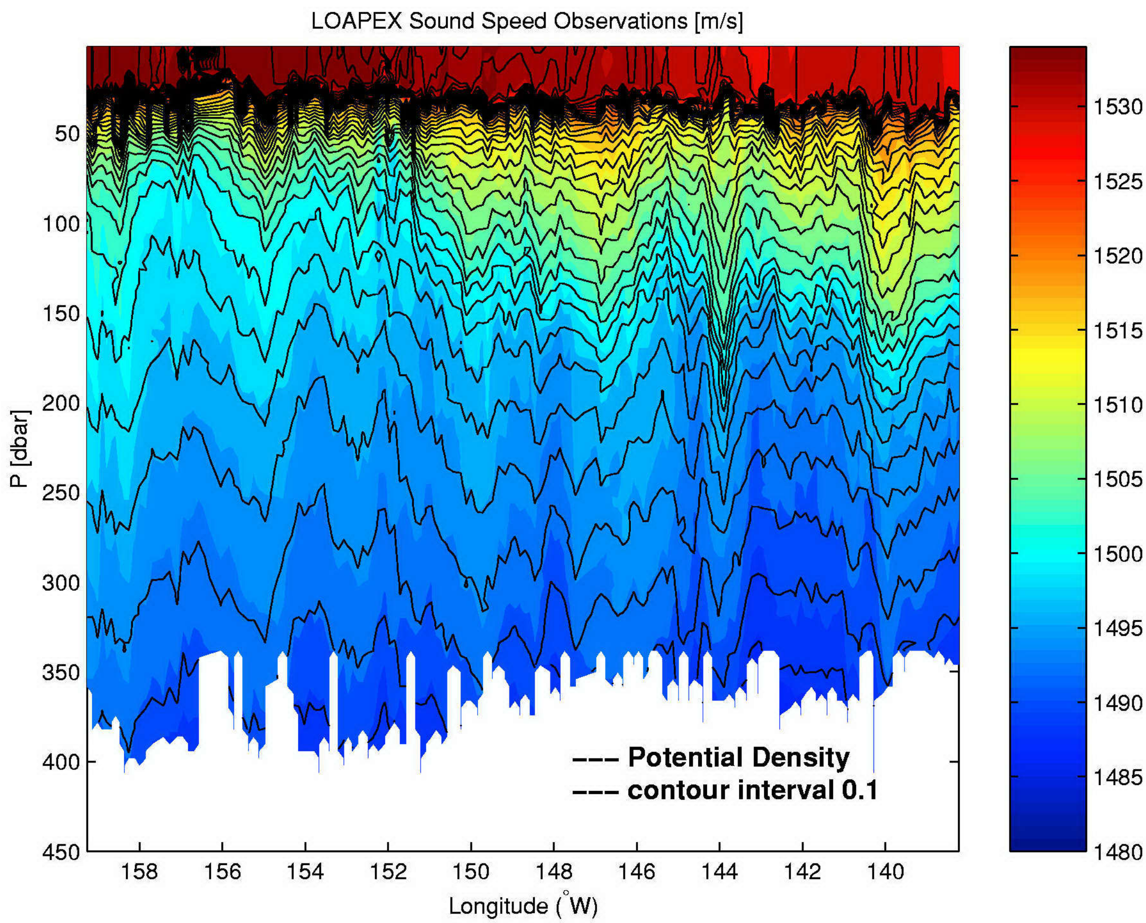

Figure 5.2. LOAPEX sound speed section with potential density contours. Casts shallower than 340 m were filled in using cubic spline interpolation in the horizontal.

In an attempt to disentangle intrusive and displacement contributions to sound speed fluctuations, we computed sound speed along isopycnals, and sound speed fluctuations from isopycnal displacement relative to the mean sound speed profile. The upper panel of Figure 5.3 shows an example of these calculations for one isopycnal near 100 m depth, and the lower panel shows the sound speed variance contributions as a function of several isopycnal depths. For both the intrusive and displacement sound speed fluctuations as a function of longitude, a linear trend has been removed, and the displacement series has both internal wave and mesoscale contributions. Both intrusive and displacement effects are seen to be largest near the surface, and are of comparable order of magnitude.

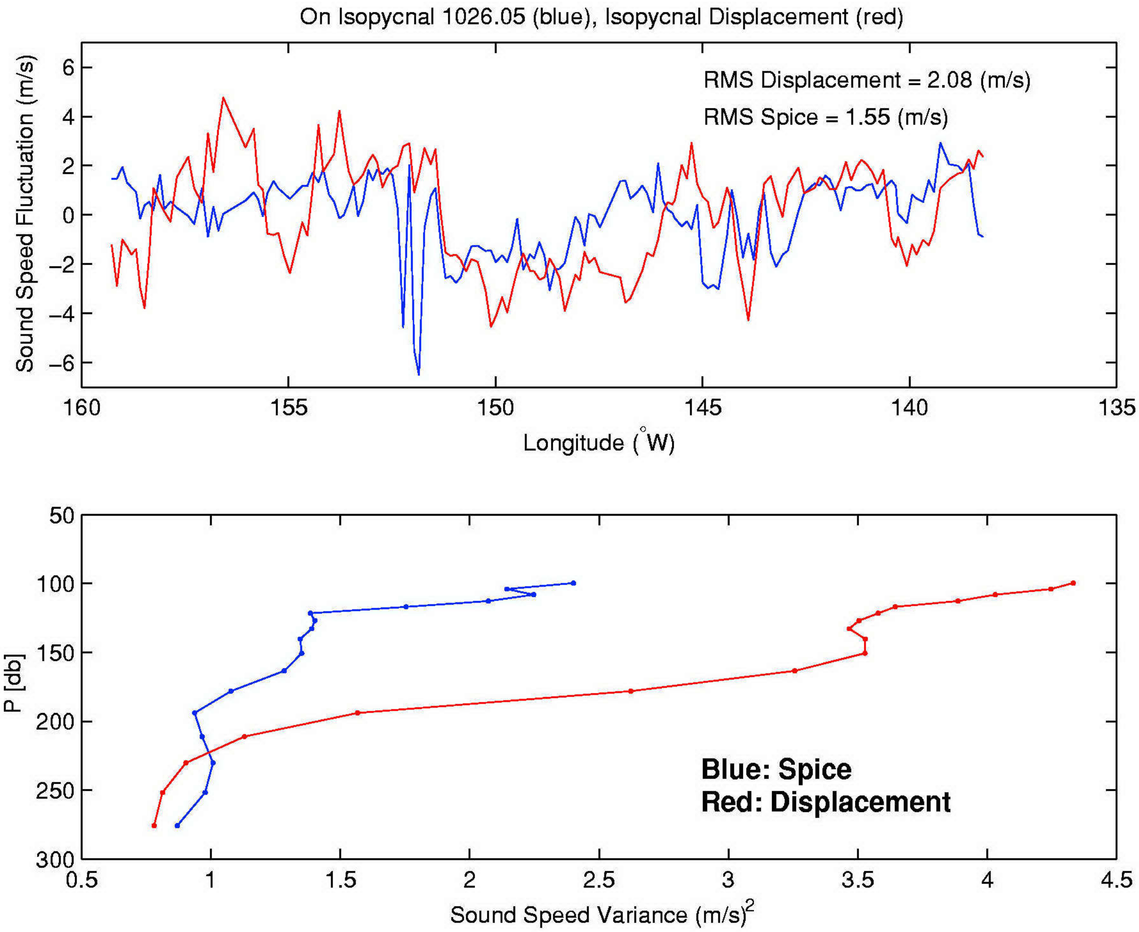

Figure 5.3. Separation of intrusive and displacement effects on sound speed. Upper panel shows an example of sound speed fluctuation along the 1026.05-kg m^{-3} isopycnal, and the corresponding sound speed fluctuation of that isopycnal displacement relative to the mean sound speed profile. Lower panel shows sound speed variance separated into intrusive and displacement contributions as a function of depth (mean isopycnal displacement).

This cruise marks the first operational use of the UCTD system by a crew other than the UCTD developers.

Ocean Depth CTDs

Full water depth CTD casts were done at stations T250, T500, T1000, T1500, T2300, T3200, and Kauai. At the T50 station problems with the cable connecting the conductivity cell and the pump limited the cast to a 2500-m maximum depth. Figures 5.5 and 5.6 show sound speed and buoyancy frequency derived from the seven CTD casts along the T50–T3200 section. Deep sound speeds and buoyancy frequencies are very

consistent across the section. The sound channel axis is seen to deepen after passage through the front at 153°W.

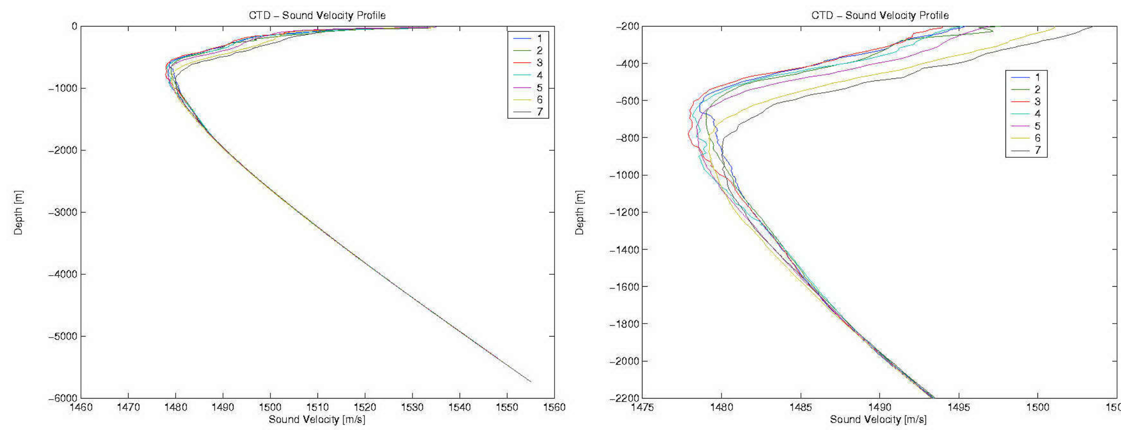

Figure 5.4. Sound speed profiles from the LOAPEX CTD section. Curves 1–7 correspond to stations T50, T250, T500, T1000, T1600, T2300, and T3200. Right panel displays upper ocean variability.

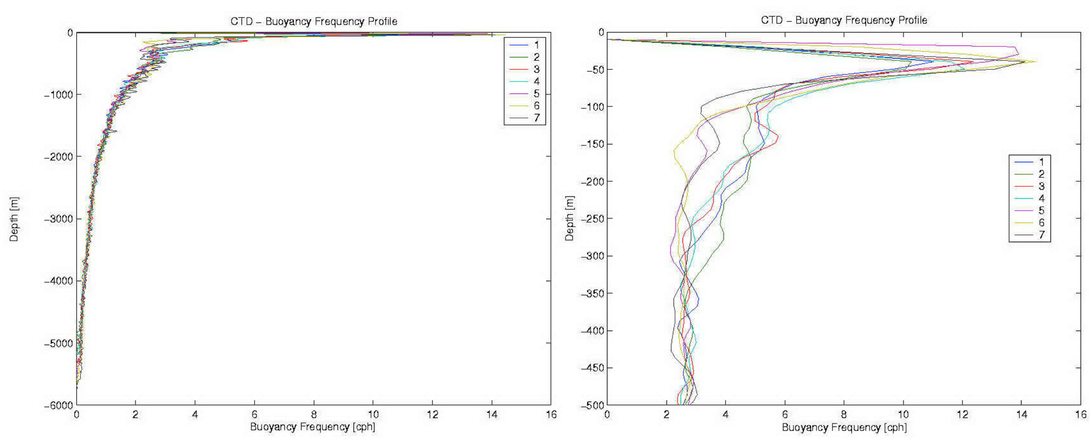

Figure 5.5. Buoyancy frequency profiles from the LOAPEX CTD section. Curves 1–7 correspond to stations T50, T250, T500, T1000, T1600, T2300, and T3200. Right panel displays upper ocean variability.

Water Samples

During each CTD cast water samples were taken at 12 depths starting about 100 m off the bottom to 1600 m depth. The water samples will provide deep salinity values, and will be used by Professor Johnson at the UW for studies of silica and nitrate plumes from hydrothermal vent systems.

XBTs

During the LOAPEX sections between T50 and T3200, 102 XBT casts were made to resolve temperature variability at horizontal resolution of 25–50 km and larger. During the UCTD operations XBTs were deployed every 50 km, and after the suspension of UCTD at roughly 160°W, the XBTs were dropped every 25 km. Overall 72 T-6 (760-m depth), 12 Deep Fast (1000-m depth), and 15 T-5 (1830-m depth) XBTs were deployed. Figure 5.6 shows the observed temperature fluctuations from the XBT data. To the east there are a few strong near surface features (0–200 m), while to the west some moderate strength, but large vertical scale features are evident (perhaps internal tides).

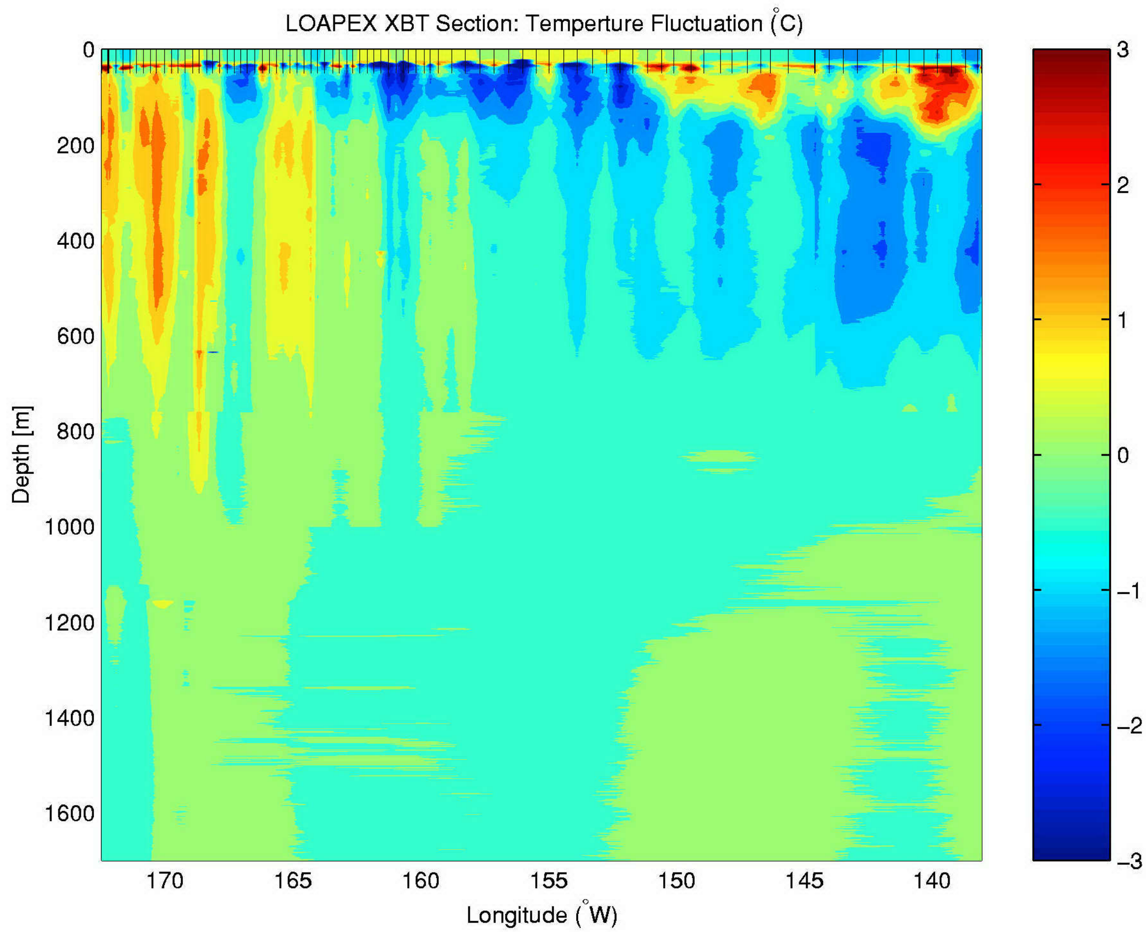

Figure 5.6. Temperature fluctuations from the LOAPEX XBT section. Black ticks in the top of the panel mark where casts were made. Probe depths varied between 760 m, 1000 m, and 1830 m. Much of the deep section below 760 m is filled in by horizontal interpolation.

Multibeam Sonar

The ship's multibeam system obtained bathymetric data along the LOAPEX transmission path from the VLAs to T3200. Figures of the bathymetry are shown in Appendix 3; no significant bathymetric obstructions were detected.

ADCP

During station and transect time the ship's ADCP system provided profiles of horizontal current at ensemble times of approximately one minute. Of fundamental importance to acoustics is the current shear (Figure 4.10).

Seagliders

The two APL-UW Seagliders were deployed the morning of 14 September at station T50. During the setup, self-testing, and deployment the use of the Iridium satellite phone to talk with Charles Eriksen at UW proved invaluable. A picture from the deployment of SG023 is shown in Figure 5.7. The small crane on the starboard side was used. Both ends of the slip line shown ran through the crane hook to keep them vertical; a strip of masking tape was put around the lines and the tail at the last moment to keep them seated in the tail fin notches while it was free floating without tension. After it was confirmed the glider was positively buoyant, the slip lines were pulled off (breaking the masking tape). This worked flawlessly for SG023, the first one deployed, but for SG022 one end of the slip line fouled on the antenna. As a result the glider got perilously close to the ship, and in fact went out of view under the stern and reappeared aft. While subsequent good performance implies no damage occurred, there is clearly room for improvement in the deployment method.

Seaglider 022 first headed east to the VLA mooring site, then turned around and headed along the LOAPEX path to station T1000. Upon reaching the latter station, it turned toward the Kauai source site for pickup. It is presently diving to 990 m and averaging 17.5 km/day (0.20 m s^{-1}). Estimated time of arrival at the Kauai source is 7 March 2005. The track of Seaglider 22 is shown in Figure 5.8.

Figure 5.7. Seaglider 023 in the process of being deployed

Seaglider 023 appears to have a temperature sensitive attitude sensor. The pitch and roll indications are unreliable. However, it is able to navigate towards its target and its energy use otherwise appears about normal. SG023 executes more roll maneuvers than it might otherwise, and the trim evolution has taken longer without reliable pitch and roll information. The GPS and communications systems are functioning normally. Scientifically, the loss of good vehicle attitude information has eliminated reliable salinity and oxygen measurements. Temperature profiles should still be good, although the horizontal position uncertainty associated with each sample is larger than normal. Because of this situation the plan for SG023 was changed. Its track to date is shown in Figure 5.9. After proceeding south to intersect the geodesic between the VLA and the Kauai source, it turned to fly along the geodesic to the Kauai source and pickup. It is presently diving to 990 m and averaging 16.4 km/day (0.19 m s^{-1}). Estimated time of arrival at the Kauai source is also 7 March 2005. Plans for the pickup of both gliders are yet to be determined.

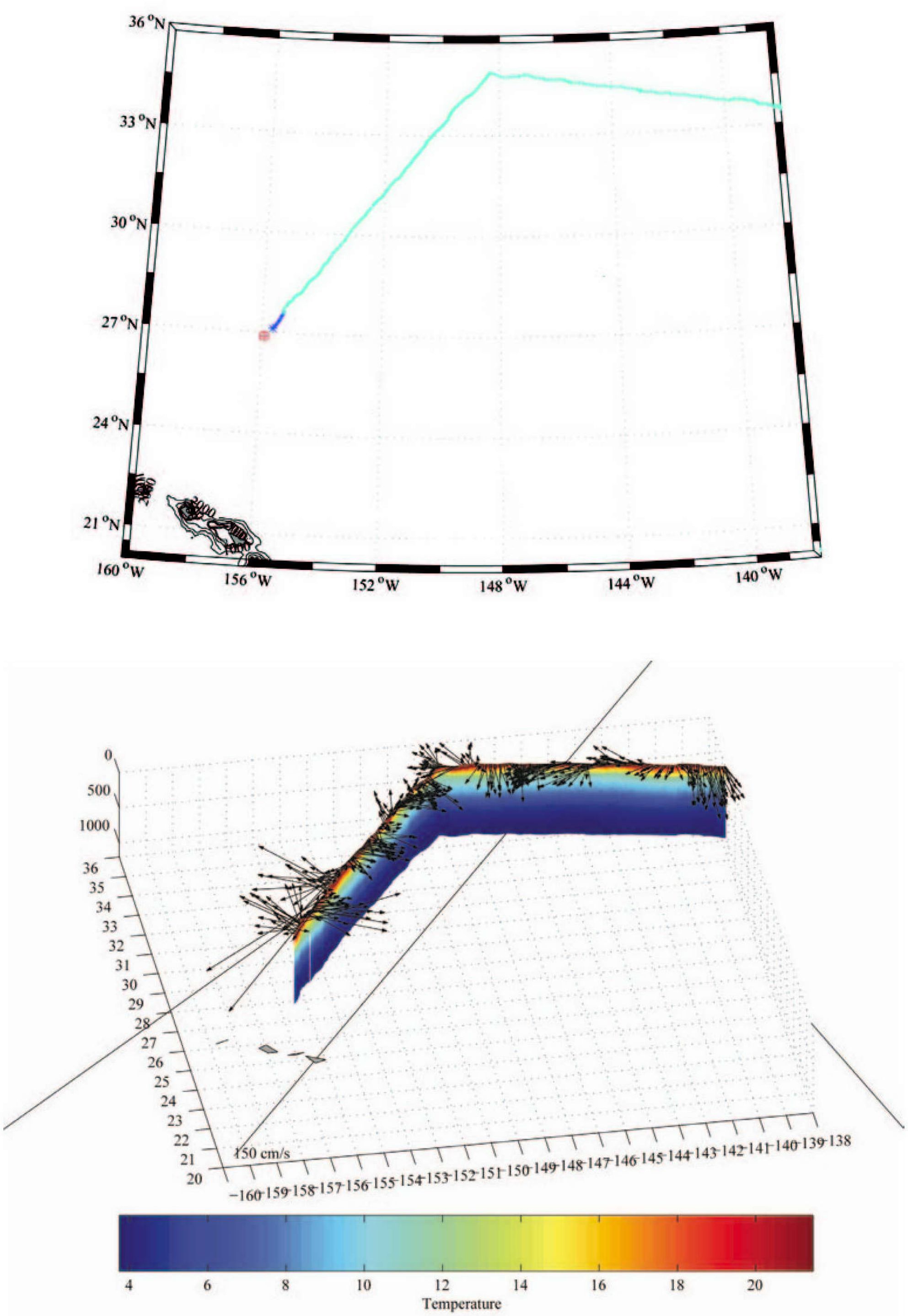

Figure 5.8. Seaglider 022 track as of 2 February 2005, with corresponding temperature section and depth-averaged velocity vectors

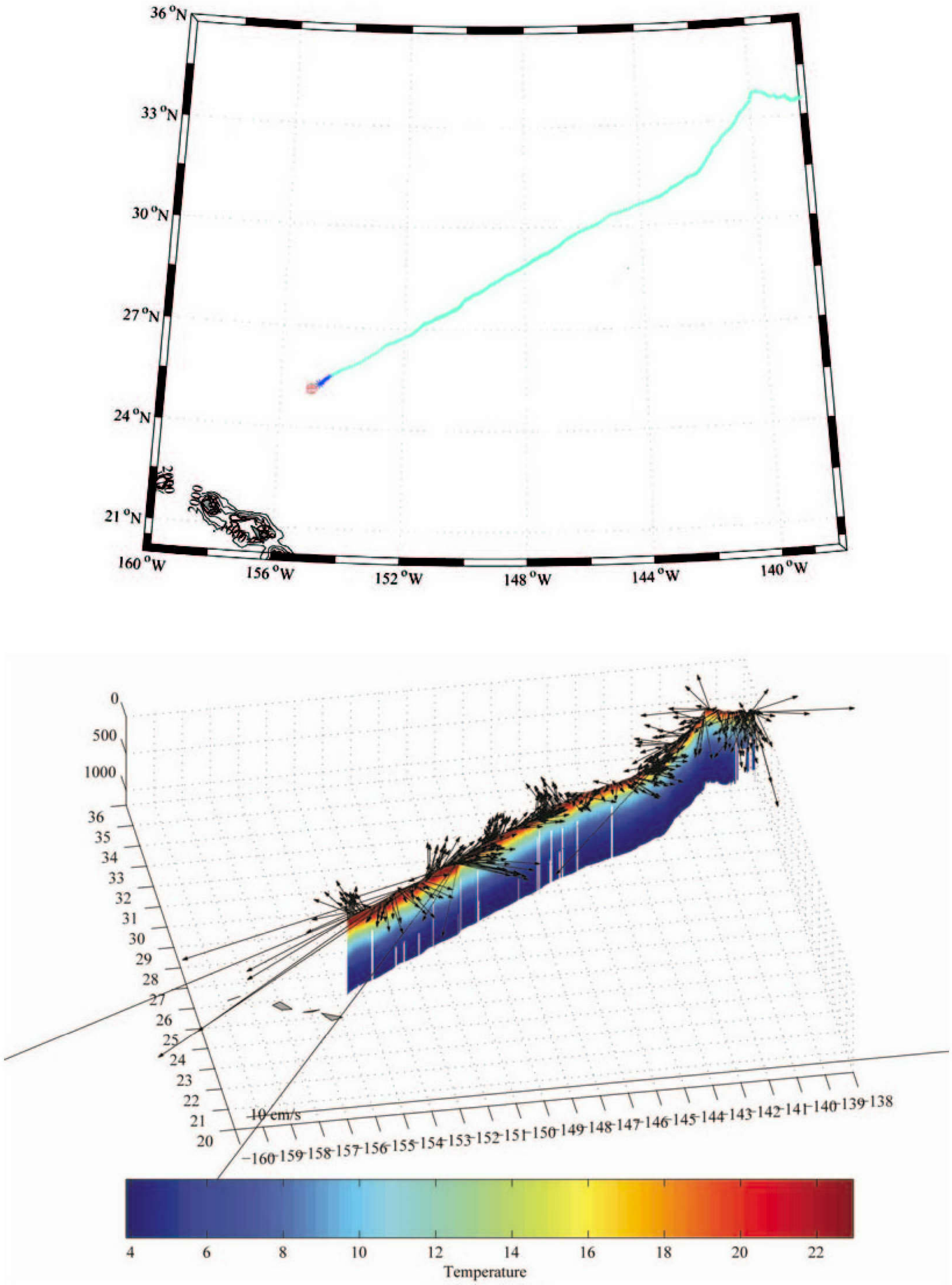

Figure 5.9. Seaglider 023 track as of 2 February 2005, with corresponding temperature section and depth-averaged velocity vectors.

Both gliders have a RAFOS receiver and were programmed to listen to RAFOS transmitters maintained by Curt Collins (NPS). SG022 has measured reasonable travel times with corresponding ranges to 1900 km. SG023 has not reported any reasonable travel times. Temperature sections as measured by the two gliders are shown in Figures 5.8 and 5.9.

Data from the gliders can be accessed at the Web pages: http://subix.apl.washington.edu/cgi-bin/all_missions.cgi?AT=1 http://iop.apl.washington.edu/seaglider.

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7. Appendix 1: LOAPEX Cruise (LFEX01MV) Summary Log

Note: The times of day mentioned in this log are local time unless otherwise specified. The transmission #s for each station are the same as those listed in the *Cruise Plan* (*Mercer and Howe*, 2004) as are the transmission times. The actual transmission times differ by a few seconds and are recorded in Appendix 2. The term impedance plot actually refers to plots of both the impedance and the admittance.

Pre-mobilization 30 August – 6 September

During this period the science van and the storage van were loaded and secured aboard the vessel. A significant effort was required to determine the necessary placement and orientation of the science van deck mounting plates. The air tuggers were positioned and tested. The science van was powered, but the voltage from the ship was only 207 V. The ship was asked to rectify this problem. The DOS computer was satisfactorily exercised and the science van GPS was mounted and tested. The high-pressure gas manifold on the HX-554 frame was better secured and the gas valve on top of the HX-554 was re-mounted (after attaching the battery leads). The 0.680 cable termination was re-dressed with stainless steel wire to minimize fraying. All of the shipments from suppliers, APL-UW, and WHOI arrived and were loaded except the final Seaglider shipment from APL-UW and the final transponder shipment from Benthos. The ship's main crane is under repair as is the starboard A-frame. The mounting pipe that extends into the ship's well for the Benthos transducer is being refurbished. An adapter plate will have to be fabricated to mount the transducer. Because the mounting pipe has to be raised and lowered with the ship's crane at each station, the use of this deployment method is in question.

Mobilization 7 September

CTD/Rosette – The CTD, but not the rosette, was tested during the at sea trial last week. It is operational with the exception of the level wind, which is being repaired at this time.

UCTD – Nothing has arrived from Dan Rudnick yet, it is expected on Thursday.

OBSs – The OBSs have arrived and are still setting on the dock.

XBTs – XBTs have arrived and are stored in the main lab.

MicroCat – The MicroCat arrived today.

S-4 Current Meter – The WHOI S-4 current meter has arrived and it is stored in the main lab.

Multi-beam Sonar – The multibeam sonar attitude subsystem was damaged during the power failure that happened during the previous cruise. It is now operational.

Interrogators – The interrogators are in the storage van.

Transponders - The transponders are in the main lab.

All GPS Navigation – The C-Nav receiver and antenna were installed today. The connection to the DP-system will await the Captain's approval. The science van GPS is operational.

Seagliders – Most of the Seaglider hardware has arrived with the exception of the batteries and one fairing/cradle. Mike Miller (APL-UW) found that the batteries are still sitting at Emery. He is trying to locate the other fairing/cradle.

Calibration Hydrophone – Not tested yet.

Acoustic Doppler Current Profiler – The ADCP Ocean Surveyor 75 was tested during the recent sea trial and is operational. The narrow beam ADCP is not operational.

Benthos Deck Boxes – Both units are aboard. Deck Box #1 was used to test its transducer. This transducer will be mounted on the pipe that extends through the ship's well.

Acoustic Valve – The acoustic valve has not yet been tested aboard the ship.

HX-554 Acoustic Source – The HX-554 has not yet been tested.

Transmission Software – Rex has confirmed that the transmissions go out at the proper second. There is approximately a 2-ms delay that is attributed to filtering. Need to measure this independently.

WRC Sweeper Source – The sweeper has arrived and will stay on the dock until crane services are available tomorrow. Dave installed the sweeper deck box and GPS cable in the main lab.

Control Van Electronics – The ship's transformer did not provide adequate voltage (only 208 V) to the science van. We installed the APL-UW transformer to improve the voltage. The ship now provides 239 V to the van while dockside.

Winch – The winch was powered briefly today after the voltage was increased.

Air Tuggers – The air tuggers tested ok during the pre-mobilization.

High Pressure Compressor – The HPC motor starter circuit is not working properly due to water damage. Karig says he can work around it by manually controlling two pressure valves.

Low Pressure Compressor – The LPC tested ok during the pre-mobilization.

Mobilization 8 September

CTD/Rosette – Repairs are continuing on the handling system. The starboard A-frame has been repaired and hopefully we will use it for CTD deployments.

UCTD – UCTD hardware is expected to arrive on Thursday.

OBSs – OBS systems were checked out today. It was decided that they will just hang their test transducer over the side as opposed to using the ship's hull transducer. Once we arrive at the first OBS station, all of the releases will be tested at once in a rosette at a depth of 4000 m.

XBTs – The launcher has not yet been examined.

MicroCat – The MicroCat is working properly on the bench.

S-4 Current Meter – The S-4 is checking out fine on the bench. Colosi will probably place it over the side dockside to attempt to get a current measurement.

Multi-beam Sonar – The multi-beam sonar is reported to be operational.

Interrogators – On board, no bench testing yet.

Transponders – On board, no bench testing yet. The last of the transponders should arrive tomorrow morning.

All GPS Navigation – The science van GPS is working fine. The C-Nav system is working and has been input to the ship's DP system.

Seagliders – All Seaglider hardware has arrived and Howe has begun the assembly of the units.

Calibration Hydrophone – The calibration hydrophone (ITC 8211 S/N001) is currently being used to monitor source tests.

Acoustic Doppler Current Profiler – No change.

Benthos Deck Boxes – No change.

Acoustic Valve – The acoustic valve was tested on deck using a bucket of water for the sending transducer. And the valve was exercised during the dockside deployment of the source.

HX-554 Acoustic Source – The HX-554 was successfully deployed dockside today. Its weight in water without air was 3000 pounds as measured with the Dillon scale. The weight in water with air in the center cavity was 2900 pounds. An in-air impedance test compared almost exactly with one taken aboard the *New Horizon* and the in water tests are being collected this evening.

Transmission Software – No change.

WRC Sweeper Source – The Sweeper source was loaded aboard today and secured on the starboard fantail. Patricia Cheng, Garth Engelhorn, and Bruce Howe received operating instructions from Dave Horowitt. The "venting plug" was installed by Matt Norenberg.

Control Van Electronics – The control van electronics appear to being working fine so far. Signals have been sent to the dummy load first, then to the source while on

deck, and currently to the source while hanging in the water dockside. Arrangements have been made to leave the source in the water over night.

Winch – The winch worked satisfactorily during the dockside deployment.

Air Tuggers – The air tuggers worked nominally during the dockside deployment.

High Pressure Compressor – Karig received the circuit diagrams of the control electronics today. He expects a replacement relay to arrive tomorrow. He believes that the HPC can be operated even if the replacement part does not fix the problem.

Low Pressure Compressor – The LPC worked fine with the air tuggers today.

Mobilization 9 September

CTD/Rosette – The CTD deployment system has been repaired and the CTD will be deployed with the starboard A-frame.

UCTD – The UCTD system has arrived and has been installed. The deployment hardware has been checked out and the computer system is in the process of being checked.

OBSs – No change.

XBTs – No change.

MicroCat – No change.

S-4 Current Meter – The S-4 was not deployed dockside.

Multi-beam Sonar – No change.

Interrogators – Both NPS interrogators have been tested on the bench.

Transponders – The last few Benthos transponders arrived today.

All GPS Navigation – All GPS systems are working. The C-Nav system scatter plot shows a spread of less than 1 m dockside. Most of that may be due to ship motion. The C-Nav display is reporting an accuracy of about 0.1 m.

Seagliders – Both Seagliders have now been assembled and tested.

Calibration Hydrophone – A source of noise on the hydrophone channel as displayed on the oscilloscope was eliminated.

Acoustic Doppler Current Profiler – No change.

Benthos Deck Boxes – No change.

Acoustic Valve – No change.

HX-554 Acoustic Source – The source was recovered this morning. An impedance test revealed the same curve as yesterday.

Transmission Software – All transmission files have been tested. CRON has been run successfully several times. We may still change the 68-Hz M-sequence to a slightly different frequency.

WRC Sweeper Source – Placed a large sign on the frame warning people to not set anything on the frame or housing.

Control Van Electronics – All control van electronics are working properly. Full power signals (all types including the impedance tests) were sent into the dummy load. The PA drive setting was tested for repeatability and was found to be perfect.

Winch – The winch was used to recover the source.

Air Tuggers – The air tuggers were used to recover the source.

High Pressure Compressor – Karig installed a new relay in the HPC and it now works satisfactorily. The source frame air bottles are being filled.

Low Pressure Compressor – The LPC was used to recover the source.

10 September – In Transit to Deep VLA

Note: We were scheduled to leave port at 0800, but due to a problem with the ship's thruster (improperly wired rpm gauge) we were delayed until about 0830. A safety drill was conducted at 1230. Due to submarine transit lanes the UCTD trial deployments and training were delayed until tomorrow. We have been on a westerly course all day and are making 12+ knots. We anticipate being at the first OBS deployment site around midnight Monday, or early Tuesday morning the 14th of September.

The multi-beam Sonar, ADCP, and GPS systems are working. A flat panel display of P-code time, heading, speed, and bathymetry has been installed in the science van.

The display on the DOS computer failed today. Rex installed a VGA video card and a replacement monitor. There is no change with regard to the other systems.

11 September – In Transit to Deep VLA

Note: Continuing to steam on a westerly course at 12+ knots. A significant effort was made today in training personnel on the UCTD. Training sessions on the UCTD will continue tomorrow and Monday. Rex will remove one of the spare DOS machines from the storage van and prepare the software on this machine so that it would be ready it case it was needed. Rex created "config" files that incorporate both the M-sequence and prescription FM transmission files. All systems appear to be ready at this time.

12 September – In Transit to Deep VLA

Note: There was a briefing to the science team, ship's captain, and some of the crew on the LOAPEX.

It was decided to deploy the S-4 current meter below the acoustic source, and the interrogator and MicroCat above the source. Karig is preparing the rigging.

Because the resonant frequency of the acoustic source is significantly lower at shallower depths, we selected an approximate frequency of 68 Hz for the M-sequence transmissions at 350 m depth. Howe evaluated several different frequencies in an attempt to optimize processing issues and data recording issues. An M-sequence signal with a carrier frequency of 68.2 Hz was deemed to be the best and has the following characteristics:

	Sampling Rate		
	300 Hz	**1200 Hz**	**2400 Hz**
f	68.2	68.2	68.2
digits	1023	1023	1023
Q	2	2	2
Period (s)	30.0	30.0	30.0
Digit (ms)	0.0293255	0.0293255	0.0293255
Samp/digit	8.7977	35.1906	70.3812
Samp/Period	9000.0	36000.0	72000.0
Samp/W1	327360.0	1309440.0	2618880.0
Samp/W2	90024.0	360096.0	720192.0
Period/W1	36.373	36.373	36.373
Period/W2	10.003	10.003	10.003

Note: W1 and W2 are the recording windows on the VLAs in seconds. It was not considered significant that fractions of a period are missed in the VLA recording compared to the processing ease of having integer numbers of samples per period and samples per recording window.

Training on the UCTD will continue today. It was also decided to have a discussion about the OBS deployments with participants around 1800 on Monday 13 September. We are now expected to arrive at the first OBS site around 1900–2000 on the 13th. Calm seas have allowed us to make way at 13+ knots.

Two methods of deploying the Seagliders from the ship were discussed. Both methods utilize a line around the tail fins and the small deck crane. In the first method

(currently the one we have decided to use) a piece of masking tape would hold the line in taut around the fins while determining if the glider will float. Once we believe it is slightly positive buoyant, a snap hook is released on the crane's hook allowing both ends of the slip line to fall free. At that time the shipboard ends are separated to pull apart the tape and then one end of the slip line is released while the other end is pulled through and back to the ship. In the second method a loop is tied around the fins and the boathook/knife combination is used to free the glider once it is known that it floats.

This evening we tested all of the transponder balls on the bench with the deck box transducer. It was decided to use all but two (special feature units) of the old APL-UW transponder balls first, i.e., at shorter ranges from the VLA, because we deem them less reliable than the new units.

13 September – Arrival at Deep VLA

Note: Although the Seabeam has been operational, some fault indicators are lit. Geoff will try resetting the DSP cards while we are at Station T50. We arrived at the Deep VLA (actually OBS site 4) at about 2030. The initial effort was towards the wire test for the OBS releases. The planned depth for the wire test was 4000 m but the wire jumped the sheave on the winch and the lowering was terminated at 3000 m. All of the releases tested satisfactorily at this depth. With some effort the wire was replaced on the sheave and the rosette assembly of releases was brought back to the surface. All of the OBS electronic assemblies were bench tested and were ok except #069. After this case was opened and the battery termination reconnected, the fault (`could not access the disk`) disappeared. The following table provides information regarding the OBS deployments:

OBS/Rel ser#	Site#	Drop Time (UTC)	LAT N	LON W
063	4	0825	33 23.8505	137 40.9471
023	3	0902	33 25.1121	137 39.6872
061	2	0935	33 26.3790	137 40.9503
069	1	1017	33 25.1104	137 42.2816

While holding station for the release wire test it was noted that the dynamic positioning (DP) system would not accept the C-Nav GPS receiver as a reference. It was decided to investigate this problem on the next day.

14 September – Arrival at Station T50

Note: Because the OBS deployment ended near the transition to the 0000–0400 watch, there was apparently some confusion about starting the UCTD data collection while on route to Station T50; and by the time the 0400–0800 watch came on, the ship was almost at T50. We did, however, get the transponder ball deployed. Transponder 38960 was deployed at 1234 UTC. The position was 33 30.1739, 138 09.172. This is 45 km from the deep VLA and 5 km short of T50. In addition a T5 XBT was dropped at 1200 UTC. The location was 33 28.97656 and 138 03.66406.

Because of the early arrival the CTD cast was begun well before breakfast. A problem in the downcast developed at about 2600 m. There were multiple fault indications and the pump stopped. When the CTD was brought back up to about 100 m the pump started again. Furthermore, some of the faults were traced to a computer problem. Nevertheless, when the CTD was lowered to a depth of about 1100 m the pump stopped again. The CTD was brought aboard; a faulty connector between the conductivity sensor and the pump was the problem. A replacement cable/connector was located and installed.

The problem with the C-Nav being accepted by the DP was simply a menu selection in the DP software. Once this box was "checked" the DP accepted the C-Nav. (*Note*: the C-Nav data was actually "named" Ashtech because of the pre-existing port name.)

The next major activity of the day was the launching of the Seagliders. Preparations for launching are significant. The first glider (#023) was launched at about 1000 and departed successfully. The second glider (#022) was launched at about noon time and although the launch itself was straightforward the glider immediately turned toward the ship once it was released and damaged its oxygen senor in a collision with the ship. Otherwise this glider also departed from the ship after passing its post deployment tests.

While the CTD was being repaired, preparations for the launch of the HX-554 source began. The S-4 current meter was rigged to hang 50 ft below the base of the source frame. The deployment of the source began around 1345. By 1400 the source was in the water at a depth of 20 m. An impedance test without air in the cavity appeared normal. Unfortunately, some delays in the preparations of the interrogator postponed further deployment until about 1430. The interrogator and the MicroCat were mounted above the source. The source reached a depth of 800 m at approximately 1530. At this time the reference hydrophone was still being lowered to a depth of 575 m with the hydro-boom. The hydrophone cable has to be taped to the hydro wire every 10 ft. or so and this takes considerable time. In addition, the Benthos deck box transducer was mounted on the wire at a depth of about 10 m.

It is noted that the ADCP, C-Nav, and deck box/transponder combination were all collecting data when the source became ready.

Once the acoustic source reached its depth of 800 m, another impedance plot was made. The next step was to activate the acoustic valve so that air could enter the inner chamber of the transducer. We allowed approximately one hour for this filling. Due to an undiagnosed problem with the monitor hydrophone audio signal we could not hear the reply from the acoustic valve. The impedance plots were changing as expected after the open valve command was sent.

Following some very brief low-level testing with a 65-Hz CW signal we switched to a 90-s M-sequence. We transmitted this 195-dB file (for 800 m) with the PA drive setting at half its normal value of 304. We expected a source level of 189 dB and got just that. We then increased the PA drive setting to 304 and got a source level of 194.2. We considered this satisfactory for the time being and moved on to the PFM signal. We again set the PA drive to its halfway point for a 195-dB PFM transmission at 800 m and calculated a source level of 190.2 dB. The next test was at a full PA drive setting and the result was a source level of 195 dB. We then started `CRON` so that the scheduled transmissions began. We plan to raise the source to a depth of 350 m tomorrow morning after breakfast. Transmissions under `CRON` will be monitored by the watches throughout the night.

15 September – At Station T50 and Begin Transit to T250

Note: All transmissions through the night occurred as planned. At 0830 we began raising the source to 350 m and were at the new depth by about 0850. (The 12-kHz echo sounder measured a depth of 345 m.) We then began a series of tests to confirm that the pre-programmed signals would produce the correct source levels. At 350 m our plan is to transmit the M-sequence at 194 dB and the PFM at 195 dB. We began by transmitting a 90-s M-sequence designed for 350 m with the PA drive dial at the 152 position (half that planned for a 194 dB signal). The result was 188 dB, right on. We then transmitted another 90-s M-sequence with the PA drive dial at 304. The result was 194 dB.

The next transmission was a calibration test for the PFM. Again with the PA drive dial at 152 we determined a source level of 190.7 dB. This was a little higher than expected so we calculated that a PA drive setting of 249 would be appropriate for this signal and this depth. The result for another 90-s PFM with the dial at 249 was 195.7 dB. This is within acceptable accuracy.

The M-sequence source levels are calculated using an evolved form of Kurt Metzger's software. The travel time from the source to our monitor hydrophone is one of the outputs. This time is used to calculate the distance between the two and the corresponding spreading loss. Since last evening there has been some discussion about the correctness of this travel time measurement. It may in fact have some delay times that are unknown. The estimate of the distance between the source and the monitor hydrophone based upon wire and deck measurements is 228 m. The acoustic distance measurement yields 286 m while the source is at 800 m and 271 m while the source is at 350 m. This difference seems too large. At site T50, which is very close to the VLA, we

decided to stick with the acoustic measurement because it errors on the safe side; i.e., predictions of source level are about 2 dB higher than otherwise. We are in the process of attempting to resolve this discrepancy but have more faith in the direct physical measurements of distance.

Planned transmissions began at approximately 1100 local and continued through the day until the last transmission at Site T50 at approximately 1800 local.

Around mid-day we learned that Seaglider #023 was experiencing difficulties. Apparently erratic roll angles were occurring during the deep dives. The pilot's plan in Seattle was to leave the glider on the surface in the hope that we would attempt a recovery. After recovering the source at T50 around 1900 local, we planned to transit to the Seaglider position. The Seaglider can call in its GPS position every 2 min while on the surface. We learned, however, that after its last surfacing it was commanded to complete a few shallow dives. We believe the intention was to minimize drift of the glider while we were on route to pick up the glider. Unfortunately, the glider never re-contacted the pilot. Even though it was expected that the glider was not on the surface, using its last known position and measurements of the surface current we made an estimate of its position and headed for that location. We arrived at this site around 1945 and began transmitting an acoustic signal with the Benthos deck box and transducer. Depending upon the PA drive setting there were at times several replies. There did seem to be some consistent signals arriving with round trip travel times of 6 s. The ship was moved in a southerly direction in an attempt to reduce this travel time. However, when the move was completed, around 2015, the acoustic signal could not be recovered. It was decided to abandon the search for Seaglider #023. The rationale for doing so was as follows: 1) the likelihood of the glider being on the surface, and not contacting the pilot was considered very small; 2) even if it was on the surface, there was no acoustic signal at this time; and 3) even if the acoustic signal were regained by moving to some other location, it would be nearly impossible to home in on the device to a distance that it might be spotted visually at night in any reasonable amount of time. We departed the site at 2100 on route to T250.

16 September – Arrival at Station T250

Note: As we were heading into Station T250 this morning around 0530, a Benthos transponder ball was deployed without removing the relay magnet. Fortunately, it was realized quickly and another transponder was deployed. The CTD cast was begun at 0600. Again, unfortunately, the CTD failed; this time at 100 m. The CTD was recovered and more inspections began. Later in the day a test revealed that the main cable from the CTD unit had an open lead. Hopefully, this is the problem. A CTD cast will probably be scheduled near the end of the T250 station.

We did receive some good news about Seaglider #023. Apparently it has reported in and is still operable. We do not know how the erratic roll situation has changed, if at all, but we are hopeful that it will reach its destination near Kauai.

We noticed today that the receptions from the T250 transponder ball as replied to and received on the Benthos deck box were much more consistent than at T50.

Since the CTD had failed we prepared to deploy the acoustic source earlier than expected. The source was deployed to a depth of 800 m (800 m also indicated on the ship's echo sounder) and the monitor hydrophone was lowered to a depth of 575 m on the hydro wire. Most of the issues regarding the absolute source level calibrations have been resolved. The remaining question is the exact value of the source delay time. Kurt Metzger's old files indicate a delay time of 27 ms, while Rex Andrew's numerical model calculations predict 13 ms. The difference is small and amounts to about 1 dB. We are currently using the average value of 20 ms, so we should be within 0.5 dB. This has resulted in a new standard PA drive setting for the amplifier of 399 when the source is at 800 m. We do have some data with us from the test in Lake Washington, which should provide a measurement of the delay time and then we can consider further refinements.

We started planned transmissions today at about 1300 (2100 UTC). These transmissions at 800 m continued up to and including the one corresponding to the VLA reception at 0500 UTC, 17 September. The transmission scheduled to start about 0700 UTC was not completed while the source was being raised from 800 to 350 m. In addition, the transmission scheduled for approximately 0800 UTC was missed because of recalibrations for 350 m. The new standard amplifier PA drive position for 350 m is now 387. Transmissions at 350 m will continue until the last transmission at Station T250 tomorrow at about 1700 UTC. This will be an 80-min transmission. We will probably bring the monitor hydrophone up early around 0800 local time and then recover the source at about 0930. This will be followed by a CTD cast.

We will be moving our clocks ahead one hour tomorrow morning at 0200.

17 September – At Station T250 and Begin Transit to Station T500

In order to speed up the recovery process today the hydrophone monitor was recovered between 0800 and 0840. The Benthos transponder was secured just prior to this recovery. Because the 1600 UTC transmission was an 80-min signal we waited until it had completed before recovering the source. During the recovery, actually while removing the interrogator and MicroCat from 20 m above the source, the winch developed a problem affecting the emergency brake. A switch in the hand held control unit failed and resulted in the brake staying locked. While repairs were being conducted on the winch system, a CTD cast was begun around 1040. The cast came within 100 m of the 5288 m bottom depth and was successful. The water bottles did not all open for some as yet unknown reason. The CTD was back on the deck at 1430 for a total time of about 4 hr.

Immediately after the CTD recovery we tested the interrogator (s/n I-10) at a depth of 100 m for several minutes using the hydro wire boom. This interrogator was used at site T50. Because the data from station T50 were of poor quality we wanted to make sure the interrogator was functioning properly. It appeared to work well, so we are

more convinced that the transponder ball deployed near T50 was faulty. The interrogator data at station T250 are very encouraging. Typical horizontal motions of the source are 4 m peak-to-peak. Furthermore, the pressure sensor in the MicroCat also indicates vertical motions on the order of 4 m peak-to-peak.

We left station T250 at 1500, deployed a T7 XBT, and made way for Station T500. UCTD data and additional XBT data will be collected on route.

18 September – Arrival at Station T500

Note: We deployed a Benthos ball 5 km short of Station T500 this morning at 0130. By 0230 the CTD cast was in progress. The CTD was back on the deck by 0630 and the monitor hydrophone was on its way down. The taping of the hydrophone wire was completed and the Benthos transducer was mounted on the same cable at a depth of 6 m at 0730. The deployment of the acoustic source began at 0800. Even though we had to wait 30 min for the S-4 current meter, the source was at a depth of 800 m at 0918. Pressurization of the source began at 0935. Questions about the signal processing, the A/D acoustic channel, and the new appearance of the impedance plot resulted in a prolonged analysis. It was eventually discovered that there was a problem with the processing and that it was safe to transmit, even though the characteristic shape of the impedance plot had evolved. The first transmission was at 21:54:59 UTC. Initial source levels appeared to be a little on the low side but the voltage and current being used to drive the cable were about what is expected. As the transmissions continued throughout the first several hours, it was clear that the impedance plots were continuing to change and that the source level was gradually decreasing. Although the processing remained an element of concern, it was clear that the monitor hydrophone signal was decreasing even though the voltage and current from the amplifier were remaining the same. The source level for the 02:54:29 UTC transmission was about 191 dB. Because the impedance plots were beginning to look as if the source had lost internal air pressure, we canceled the PFM transmission and decided to reopen the acoustic valve. Much to our amazement, this changed the impedance plot back to more like we expected. Furthermore, a short test transmissions revealed that the source level capability had returned to 195 dB with our standard settings (amplifier PA drive = 399). We are at a loss as to how air could have leaked out of the cavity, or why it would not have been filled in the first place. (The gas valve was initially open for 80 min.) We will monitor the transmissions throughout the night. We plan to raise the source to 350 m tomorrow morning at 0430 local.

19 September – At Station T500 and Begin Transit to Station T1000

Note: The transmissions through last night and this morning went off without a hitch. At 0420 we began bringing the source up to a depth of 350 m. We lost the next transmission, scheduled for 13:54:29 UTC, due to the time required for the depth change. The impedance plot looked like it had at T250 so we performed a short test transmission.

The result was 193.9 dB (the goal at 350 m is 194 dB). The source continued transmitting throughout the day with the expected source level. The last transmission of the day was an 80-min M-sequence that ended at approximately 2120. We then recovered the source and the monitor hydrophone and were on our way to Station T1000 by 2250. We expect to arrive at T1000 around the same time tomorrow night.

20 September – Arrival at Station T1000

Note: Environmental measurements continued throughout the day during our transit to Station T1000. We did lose one of the UCTD probes during drop #84. We believe it was due to gradual damage to the spectra line near the termination. We think the damage is caused from friction between the line and the plastic housing that holds that end of the spool while re-spooling.

Transponder #72377 was deployed 5 km short of our arrival at T1000. We came on station at approximately 2030 and had the CTD in the water by 2045. The CTD was back on deck by 0045 and the source was deployed to a depth of 800 m at 0145. Pressurization began around 0145 and was completed at 0257. The first regularly scheduled transmission from T1000 began at 12:48:51 UTC. Although the impedance plot seemed to compare favorably with the last series of good transmissions at 800 m, for some unexplained reason the source level was only 190–191 dB. The voltage and current being provided by the amplifier are as expected. After several discussions it was decided to continue on with the scheduled transmissions until after transmission #8 at this station. If the level has not improved, we plan to attempt a re-pressurization as we had done at Station T500. If it still has not improved, we will most likely bring the source up to 350 m. We will also test the monitor hydrophone cable once it comes back on deck.

21 September – At Station T1000

Note: T1000 transmissions at 800 m continued throughout the early morning at a lower than expected source level of 190–191 dB. We re-pressurized the source between 0920 and 0935, but there was no change in its performance. The source was then raised to 350 m. At this depth, the performance of the source returned to its expected level. T1000 transmission #9 was preempted by the raising of the source. We are considering several options for the remainder of the cruise regarding the source's performance at 800 m.

The small hole in the UCTD bobbin was found to not line up well with the pin that passes through the plastic holder. A new hole was drilled for the pin to tighten the bobbin in the holder.

The Benthos ball that was deployed prior to arrival at Station T1000 had a 12-hr time out requiring re-enabling this morning. Unfortunately, the enable code was the same as the nearby mooring installed by SIO. The transponder was not enabled. Bruce Howe may have an opportunity to take the ship's small boat back to the transponder site

to deploy one of our spare transponders. The decision will be up to the Captain and based upon the safety of the sea conditions.

22 September – At Station T1000 and Begin Transit to Station T1600

Note: The small boat was used to return to the Benthos transponder site. Another transponder (s/n 45587) was deployed around 0900.

Near midnight on the previous night a large noise was heard on the hydrophone monitor speaker. It was also displayed on the science van oscilloscope as plus and minus 20-V excursions. The event lasted for about 2 or 3 min and then the phone went dead. This morning we brought the hydrophone and its cable on deck to investigate. There was little concern in doing this because the source had been very consistent at 350 m depth, plus or minus a few tenths of a dB. By using a makeshift time delay recorder and a cable megger, the faulty piece of cable was eventually found. About 350 m of the wet end of the hydrophone cable were removed. Isolating the fault any closer did not seem worthwhile. The cable remaining on the spool is in excess of 800 m. Although we hope to have found the only faulted portion, we won't know for sure until we redeploy the hydrophone and cable.

Transmissions continued on until the last one [#41 on the T1000 Appendix list of the *Cruise Plan* (*Mercer and Howe*, 2004)]. Art Baggeroer reports that he has been receiving our M-sequence and PFM transmissions on a single phone without code processing. At site T1600 we plan to initially place the source at a depth of 900 m for pressurization and an impedance plot. After raising the source to 800 m, we will take another impedance plot and then evaluate the status of the source. It is quite possible that we will not do any full power transmissions at 800 m. We are concerned that we may damage the source because we do not understand the previous impedance plots (they do not compare with the historical results and they do not match the numerical model output). We may then continue to raise the source to 350 m stopping at 100-m increments to take impedance plots. We will be looking for the possibility that the plots may become predictable at some depth deeper than 350 m. Perhaps the depth will be deep enough to still produce the final cutoff arrivals. The focus of LOAPEX is not on the final cutoff, but rather the earlier part of the "accordion." We are fortunate that the source has been working well at 350 m. Nevertheless, we will attempt to solve the issue at 800 m before we arrive at the final station near Kauai. The source appears to have a little less oil inside its rubber boot than normal, and this may have something to do with the anomalous performance at 800 m.

23 September – Transit to Station T1600

Note: This entire day has been spent in transit to Station T1600. UCTD and XBT casts have continued as planned.

24 September – Arrival at Station T1600

Note: During the early morning hours we ran into a small weather front. The first CTD was only to 500 m to calibrate the UCTD sensors. The second CTD started around 0230 and was completed by 0630.

Following the deployment of the hydrophone to 575 m, the source was deployed to 900 m. The source was then pressurized for 90 min. We wanted to be sure the interior cavity of the source was completely void of water. We then began a series of tests during which we raised the source in 100-m increments until we reached 400 m. The last increment was 50 m to a final depth of 350 m. At each depth we sent short, 90-s M-sequences at either 75 or 68.2 Hz depending upon the depth. We also changed the amplifier PA drive setting along with the carrier frequency of the M-sequence. The goal was to discover the transition between the fully predictable performance of the source at 350 m and the anomalous behavior demonstrated at 800 m. The following table summarizes the results. All of the data were taken with the amplifier PA drive set at 152. The predicted source levels below are at the amplifier PA drive shown:

Depth	Admittance Plot	Carrier	Predicted	@Amp PA Drive
900 m	abnormal	75 Hz	190.2 dB	399
800 m	abnormal	75 Hz	190.2 dB	399
700 m	partially normal	75 Hz	189.4 dB	399
600 m	partially normal	75 Hz	190.5 dB	399
500 m	nearly normal	75 Hz	192.6 dB	399
500 m	nearly normal	68.2 Hz	193.9 dB	387
400 m	normal	75 Hz	193.0 dB	399
400 m	normal	68.2 Hz	194.2 dB	387
350 m	normal	75 Hz	192.6 dB	399
350 m	normal	68.2 Hz	194.0 dB	387

By definition a normal admittance plot is one that closely agrees with the numerical model output. As can be seen, normal admittance behavior begins near 500 m and shallower. Also at these depths it is possible to attain source levels of 194–195 dB.

Following these tests, because the source could not be lowered deeper without bringing it back aboard and re-pressurizing the gas bottles, we kept it at a depth of 350 m for the remainder of the day. And in fact, we planned to keep it at 350 m for the remainder of T1600.

As a follow up note, the repairs that had been made to the hydrophone cable proved to be successful.

It is quite possible that by the time we reach T2300 we will transmit at both 500 m and 350 m. We want to do some propagation simulations for a source at 500 m first. We want to know if a source at this depth will adequately fill in the final arrival structure of the accordion.

25 September – At Station T1600 and Beginning Transit to T2300

Note: It was noticed around 0500 that the output level of the source had been dropping over the past few hours. At 350 m the source level for the M-sequences stayed very close to 194 dB, and if anything, tended to increase some with successive transmissions. Transmission #18 at T1600 showed a small drop in source level and transmission #19 revealed a drop of more than 0.5 dB. Transmissions #20 and #21 also showed further decreases down to approximately 191 dB. The corresponding admittance loops also indicated some definite shifts. Because the amplifier voltages and current had not changed a corresponding amount, it was felt that the source may need to be re-pressurized. This action was taken immediately and the result was that transmission #22 was back up to 194 dB.

Transmissions for the remainder of the day increased very slightly, but were less than 195 dB. It was noted, however, that the very last transmission, #34, showed a small decrease in source level, and change in the admittance plot that was similar to the change that had occurred before. It was also noted that the first transmission from T1600 was #7 and that the first sign of low gas pressure occurred after transmission #18. Furthermore, after re-pressurizing before transmission #22 the source again exhibited signs of low pressure following transmission #34. In both cases there were approximately 12 hours between the times that additional gas was needed. We will have to keep a close eye on this.

The monitor hydrophone was recovered between 1900 and 1930, and the source was pulled in between 1930 and 2000. This short recovery time, a result of great teamwork, will result in additional time at Station T2300 and one more transmission there.

On leaving Station T1600 normal XBT and UCTD casts began. A pin that holds the UCTD bobbin in place while re-winding broke during the first cast and required repairs. Our plan is to only continue UCTD work until we reach a range of 2000 km from the VLAs. This will limit the chances of losing the last remaining probe and hopefully allow it to be re-calibrated back at Dan Rudnick's lab.

26 September – In transit to Station T2300

Note: We went through another time zone this morning while on route to Station T2300. We are now 10 hours behind UTC.

The last regular UCTD cast (#174) was made this afternoon. A few test casts will be made with the two bad probes to see if anything can be learned about their condition. We also decreased the spacing of our XBT drops from 50 km to 25 km. We will now be dropping a XBT roughly every hour while in transit.

Our ETA for Station T2300 is 0300 (1300 UCT) next morning. In order to realize paths between the bottom transponder and the interrogator that are a little more horizontal, we will be dropping the next transponder 6 km from our station instead of 5 km.

27 September – Arrival at Station T2300

We arrived on station in the early morning hours. A CTD cast was completed by 0830 (1830 UCTD). We did deploy the monitor hydrophone but it was finally decided that the seas were too rough to risk deploying the source. The seas continued to be high all day, Beaufort sea state Force 5 or 6, but began to show some improvement near midnight. We hope we will be able to deploy the source tomorrow morning.

28 September – At Station T2300

By dawn we determined that the sea state had come down to Beaufort Force 4, so we decided to go ahead with the deployment. Two extra steadying lines were added to the forward side of the transducer frame. The deployment went very smoothly. The source was lowered to a depth of 500 m where it was pressurized in about 20 min. The echo sounder also indicated a depth of 500 m. The first transmission was T2300 #26 at 20:34:06 UTC. The source level was 194.6 dB.

Nine hours later, the source level fell significantly for transmission #35 to 189.9 dB. The acoustic air valve was opened for 10 min to allow air into the source. The next source transmission, #36, had a level of 193.9 dB, but the following transmission was back down to 193.0 dB. Another 20 min of air was added to the source and the next transmission, #38 was at 194.2 dB.

The source was raised from 500 m to 350 m just after transmission #38. This was around midnight.

Also during the evening we found that the Benthos transponder ball could not be re-enabled. The problem was eventually solved by switching to the spare deck box and transducer.

29 September – At Station T2300 and Beginning Transit to Station ST3200

Transmissions continued throughout the day at a depth of 350 m as planned. Air was added to the source after transmission #46 due to an expected low level as indicated

on the monitor hydrophone oscilloscope; however, it was soon realized that this was a cockpit error and additional air really was not necessary.

The Benthos transponder ball was re-enabled without difficulty today. In addition, enough specific information was received from Benthos to allow us to inhibit the requirement for periodic re-enabling of our remaining new transponders.

The hydrophone and source were recovered after transmission #52 and we were on our way to Station T3200 by 1615 (1415 UTC).

30 September – In Transit to Station T3200

We spent the entire day transiting to Station T3200.

1 October – Arrival at Station T3200

Six kilometers before Station T3200 we deployed a Benthos transponder to the ocean floor. In addition, because this was the last station on the main geodesic path to the VLAs, we deployed some of our spare XBTs as we approached T3200. Arrival at T3200 was around 1000 and the conditions were very unfavorable; the sea state was Beaufort Force 6. We were able to deploy the CTD with some difficulty and complete the cast by 1400; however, the seas remained severe all day and we were not able to deploy the acoustic source.

2 October – At Station T3200

By early this morning, the sea state had dropped to Beaufort Force 4+. We deployed the hydrophone before breakfast and started the source deployment after breakfast. The deployment was delayed while two interrogators were prepared for mounting on the source cable. One interrogator transmitted at a long interval of 15 s while the other transmitted at a 3-s interval. This will help reduce the under sampling for motions with periods on the order of 15 s. The source pressurized at 500 m in about 15 min and was ready for transmission #20 at 21:23:59 UTC.

It was noted that after transmission #28 at 06:23:59 (ten hours later) that the source level had dropped about 0.6 dB. This is usually a warning sign that the source needs to be re-pressurized. After transmission #29, when the source dropped another 1.8 dB, it was obvious that additional air was required. The acoustic valve was opened for 25 min prior to transmission #30. The subsequent level for transmission #30 was 194.4 dB.

3 October – At Station T3200 and Beginning Transit to Station Kauai

The acoustic source was raised from 500 m to 350 m after transmission #34, i.e.; around 0230. We did add air after transmission #35 because the source level was only 193.5 dB; however, it was probably not needed. The pattern at 350 m depth has been to start at a level of about 193.5 dB and then for the level to creep up towards 195 dB without adding air. The last transmission from T3200 was #41 as planned. The source and hydrophone were recovered after dinner, and following a T5 XBT we began our transit to Kauai.

4 October – In Transit to Station Kauai

We have been in transit toward Kauai all day.

After the source was refurbished at APL-UW, the test deployments aboard the R/V *New Horizon* at 800 m revealed an impedance characteristic that was different from past deployments and different from the model predictions. In particular, the admittance curve had a very discernable extra loop indicating an additional resonance. One thought was that it might have something to do with the new mounting frame. In addition, it appeared as if the lower portion of the boot was not completely filled with oil. Because the source was producing a good signal at 195 dB, there was no urgent alarm. During the first three stations for LOAPEX the source behaved much like it did during the test deployments, but thereafter the source level at 800 m dropped off significantly.

To remove our suspicions about the lower boot now being completely filled with oil we added oil today. The process involved removing the middle banding material at the base of the transformer section and then placing a cargo strap around the transformer section to squeeze oil down into the lower section. Oil was added back into the upper section through the plugs and then the process was repeated. After the last filling of the top section a total of 14 liters of oil were added. The lower boot now appears more like I expected it to, without concaving in between the dummy bars.

5 October – In Transit to Station Kauai

We are still in transit to Station Kauai. Today we removed the acoustic valve from the source frame and opened the pressure case to check the batteries. The voltage was 7.8 V, which is at the top of the "good" range.

6 October – In Transit to Station Kauai

We are still in transit to Station Kauai. Upon arrival we will deploy Benthos transponders. One will be 5 km from Station Kauai and on the geodesic to the VLA. The other transponder will also be 5 km from the station and along an azimuth that is 90º counterclockwise from the first.

We are considering several Pentaline M-sequences as candidates for an interesting signal to send from Station Kauai. The first priority, however, will be to get useful signals sent from a depth of 800 m. In addition to adding oil to the transducer, we have restricted the motion of the ten vertical bars that form the outer protective members of the source's frame. There was thought to be a small chance that these bars could be providing a secondary resonant mode.

We expect to have the transponders deployed and start the CTD by around 0700 tomorrow morning.

7 October – Arrival at Station Kauai

As a result of a higher than planned transit speed, we arrived at Station Kauai earlier than expected. The two transponders were installed as described above by 0630 and the source was ready to deploy at 0800. Because our transmission window did not open until roughly 1830 we had time to experiment with the source's behavior at 800 m. Recall that we had previously added 14 liters of oil to the transducer and had also strapped together the vertical supporting bars of the source frame in an attempt to change any possible resonances.

When the source reached 800 m the acoustic valve was opened. It was noticed that the impedance plots were changing extremely slowly. It had been suggested that the difficulties at 800 m might be due in part to the cavity really not completely filling with air during pressurization. One idea was to leave the valve open for longer than usual, close the valve and then recover the source to see how much air was left in the bottles.

During this deployment at 800 m, the impedance plots were changing so slowly that we wound up leaving the valve open for 105–120 min (we could not be sure of exactly when the valve opened). When the source reached the surface the gas system pressure was about 4000 psi. The initial gas pressure was 4500 psi meaning that only about one quarter of interior cavity had been voided of water. The gas pressure regulator was suspected. Even though gas regulation appeared normal at 500 m, it appeared that it was not so at 800 m. Upon removing the regulator and opening it we found an air filter that was significantly clogged. In addition, there were other signs of corrosion in and around the needle valve. It was clear that the entire gas pressurization system, including the bottles, needed to be refurbished. It was possible to clean the air filter and remove most of the corrosion from the regulator, but it was feared that the gas bottles and the other components of the system may also contain contaminants that would eventually reach the regulator.

After cleaning and replacing the regulator the source was re-deployed to 800 m. Although the gas filling went slower than hoped (we expect a gas filling at 800 m to take 30–40 min from past experience) we did see a different behavior in the impedance plots. We do not know if this change is due to the additional oil or the fact that the vertical support bars are restricted. We decided to leave the gas valve open because the estimated source level based upon low-level transmissions continued to rise. We eventually turned

the system over to CRON for Transmission #4 (8:32:35 UTC). The resulting source level was 194 dB. The plan for tomorrow's transmission depths will depend on how the source continues to behave at 800 m through the night and tomorrow morning.

An interesting even occurred earlier in the day when we recovered the source from the first deployment. A circuit breaker in the ship's power panel tripped and all power to the science van was lost. Unfortunately, this caused the winch to turn freely while the source was being raised. It only took a few seconds for Karig to apply the manual break, but they were exciting seconds. The system should have a motor with a built in break that automatically locks if electrical power is lost.

8 October – At Station Kauai

Transmissions continued from Kauai today with the source level in the 194–195-dB range. The source depth was kept at 800 m until the completion of Transmission #23. At this time the source was raised to 500 m. Unfortunately the time required to complete this task caused us to miss Transmission #24.

Today we added a new type of transmission. It is called a Pentaline. It is really a variant of an M-sequence. Its principal characteristic is the presence of five relatively strong tonals, one centered at the carrier frequency and two on each side of the carrier. Two Pentaline transmissions (each 20 min in duration with 5-min ramps) have been scheduled to occur just before each of the prescription FM transmissions.

9 October – At Station Kauai

Transmissions at 500 m continued this morning. The last transmission at this depth was an 80-min transmission. Near the end of the transmission, a drop in the ship's 3-phase power caused the amplifier to trip off line. The source was raised to 350 m as planned and the power drop did not repeat itself all day.

The monitor hydrophone was recovered during the last transmission from Kauai around 1900. The source was recovered starting around 2000 and we were on our way to Honolulu by 2000.

Items needing attention before the next cruise:

- Winch system repairs and modifications (in order of priority)
  - repair hydraulic system leaks (probably can be done without removing winch)
  - remove cable, clean, lube, rewind (can do at APL-UW dock area)
  - general work of documentation so others could operate/understand unit better
  - general maintenance of lubing, cleaning, checking for problems

  - replace existing hydraulic motor with brake motor (winch removal needed)
  - level wind system improvements on rollers, and for automatic following
- Compressors
  - change filters and oil on high-pressure unit
  - establish drain line on low-pressure unit
- Source
  - thorough look at gas system
  - drain and clean high pressure tanks, lines, and the regulator
  - possible methods to eliminate regulator or install easily cleanable filter
  - coat inside of high-pressure tanks
  - add pressure and temperature sensors
  - relief valve to capture air in cavity
  - consider cleaning the bender bar cavities
  - consider adding a new oil filling path
- Amplifier
  - repair current (amperage) bar graph
  - repair old style power modules as spare for old logic module
- Computer
  - update A/D software to work with new LINUX boxes

8. Appendix 2: Primary Transmission Summaries

The primary HX554 transmissions are summarized in the tables below. UTC date and time represent the "mark" time of the transmission (not the start time as registered in the file header). These times are different than those in the *Cruise Plan* (*Mercer and Howe*, 2004). Depth is the nominal transducer depth in meters. Duration is the length of the primary scientific signal, in seconds. Cable voltage and current are RMS volts and RMS amperes, respectively. Values from *M-sequence* transmissions are provided by `proc`, version dated 8 April 1998. Values for the PFMs were computed using `chansam` to extract the first waveform of the primary transmission, and MATLAB to compute the scaled RMS level.

The source levels have units of dB re: 1 μPa @ 1 m. This quantity is derived from the SPL of the direct path component, the estimated range from source to monitor hydrophone, and a spherical propagation model with a uniform sound speed of 1500 m s^{-1}.

These computations for the *M-sequence*s were done by the program `proc`, version dated 8 April 1998, with a source delay of 20.25 m s^{-1} and a "range_ref_bin" of 40.

The computations for the PFMs used `chansam` to extract the first primary wavefrom from the raw file and then a simple MATLAB pulse compression function that basebanded the primary wavefom and then correlated it against a basebanded replica produced by the system simulator. The SPL, range, propagation loss, and finally the source level were computed by hand using the arrival time and magnitude of the direct path component of the pulse-compressed waveform. Neither source delay nor processing delay were used in the range calculation, because the replica produced by the system simulator has the source delay built into it, and the MATLAB pulse compression routine does not introduce a processing delay for periodic waveforms.

For the pentalines, `chansam` was used to extract 10 periods starting at mark time, and the SPL was computed using the RMS level of the acoustic channel, scaled to in-water units and corrected for range using the most recent M-sequence-based estimate.

These tables present a cumulative total of about 5760 min or 345,600 s of transmission time, not including ramps. The total transmission data is approximately 9.95 GB (1 Hz clock, drive signal, cable voltage and current inject signals, acoustic channel, and IRIG are collected simultaneously on-board during each transmission) not including ramp time and engineering only transmissions.

The signal types represented in these tables are described below.

Type	Description
M75(195)	M-sequence, carrier 75 Hz, using the file M195.800
M68.2	M-sequence, carrier 68.2 Hz, using the file M195.350
PFM800C	PFM, designed for 800 m, scaled from the pre-cruise 800-m signal so that it achieved approximately 195 dB with the same dial settings used for the M75(195) signal
PFM350B	PFM, designed for 350 m, scaled from the pre-cruise 350-m signal so that it achieved approximately 195 dB with the same dial settings used for the M68.2 signal
PL800	Pentaline, center frequency 75 Hz, using file PENTA.800; designed for 800 m
PL350D	Pentline, center frequency 68 Hz, using file PENTA.350D; designed for 500 m, scaled to achieve 195 dB with PA dial setting 387
PL350E	Pentline, center frequency 68 Hz, using file PENTA.350E; designed for 350 m, scaled to achieve 195 dB with PA dial setting 387

Station T50 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/15/2004	3:59:23	800	1200	PFM800C	769.2	2.93	194.0	Y	c0425903.sam
9/15/2004	4:59:23	800	4800	M75(195)	738.0	3.34	192.7	Y	c0425904.sam
9/15/2004	6:59:23	800	1200	M75(195)	737.5	3.34	192.8	Y	c0425906.sam
9/15/2004	7:59:23	800	1200	M75(195)	740.9	3.35	192.9	Y	c0425907.sam
9/15/2004	8:59:23	800	1200	M75(195)	740.6	3.34	192.9	Y	c0425908.sam
9/15/2004	9:59:23	800	1200	M75(195)	740.1	3.34	192.9	Y	c0425909.sam
9/15/2004	10:59:23	800	1200	M75(195)	739.5	3.33	192.8	Y	c0425910.sam
9/15/2004	11:59:23	800	1200	M75(195)	740.6	3.33	192.8	Y	c0425911.sam
9/15/2004	12:59:23	800	1200	M75(195)	741.2	3.32	192.9	Y	c0425912.sam
9/15/2004	13:59:23	800	1200	M75(195)	741.7	3.32	192.8	Y	c0425913.sam
9/15/2004	14:59:23	800	1200	M75(195)	741.4	3.31	192.8	Y	c0425914.sam
9/15/2004	15:59:23	800	1200	PFM800C	772.7	2.90	194.3	Y	c0425915.sam
9/15/2004	18:59:23	350	1200	M68.2	765.5	4.79	191.9	Y	c0425918.sam
9/15/2004	19:59:23	350	1200	M68.2	764.8	4.82	192.2	Y	c0425919.sam
9/15/2004	20:59:23	350	1200	M68.2	765.0	4.84	192.3	Y	c0425920.sam
9/15/2004	21:59:23	350	1200	M68.2	764.6	4.85	192.4	Y	c0425921.sam
9/15/2004	22:59:23	350	1200	M68.2	764.4	4.86	192.3	Y	c0425922.sam

Station T50 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/15/2004	23:59:23	350	1200	M68.2	764.4	4.87	192.4	Y	c0425923.sam
9/16/2004	0:59:23	350	1200	M68.2	764.4	4.87	N/A	Y	c0426000.sam*
9/16/2004	1:59:23	350	1200	M68.2	764.1	4.87	N/A	Y	c0426001.sam**

*Monitor hydrophone disabled during transmission. **Monitor signal unavailable.

Station T250 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/16/2004	20:57:07	800	1200	M75(195)	954.0	4.39	195.2	Y	c0426020.sam
9/16/2004	21:57:07	800	1200	M75(195)	953.9	4.38	195.3	Y	c0426021.sam
9/16/2004	22:57:07	800	1200	M75(195)	954.0	4.37	195.3	Y	c0426022.sam
9/16/2004	23:57:07	800	1200	M75(195)	953.9	4.37	195.2	Y	c0426023.sam
9/17/2004	0:57:07	800	1200	M75(195)	953.4	4.36	195.3	Y	c0426100.sam
9/17/2004	1:57:07	800	1200	M75(195)	954.0	4.36	195.3	Y	c0426101.sam
9/17/2004	2:57:07	800	1200	M75(195)	954.6	4.36	195.3	Y	c0426102.sam
9/17/2004	3:57:07	800	1200	PFM800C	766.9	2.93	195.1	Y	c0426103.sam
9/17/2004	4:57:07	800	4800	M75(195)	953.6	4.34	195.3	Y	c0426104.sam
9/17/2004	8:57:07	350	1200	M68.2	940.7	5.96	194.1	Y	c0426108.sam
9/17/2004	9:57:07	350	1200	M68.2	939.4	5.99	194.2	Y	c0426109.sam
9/17/2004	10:57:07	350	1200	M68.2	939.8	6.01	194.3	Y	c0426110.sam
9/17/2004	11:57:07	350	1200	M68.2	940.6	6.03	194.4	Y	c0426111.sam
9/17/2004	12:57:07	350	1200	M68.2	940.3	6.04	194.4	Y	c0426112.sam
9/17/2004	13:57:07	350	1200	M68.2	940.5	6.05	194.5	Y	c0426113.sam
9/17/2004	14:57:07	350	1200	M68.2	940.6	6.05	194.4	Y	c0426114.sam

Station T250 Transmission Summary									
Date UTC	**Time UTC**	**Depth [meters]**	**Duration [seconds]**	**Signal Type**	**Cable Voltage**	**Cable Current**	**Source Level**	**Ramp**	**Filename**
9/17/2004	15:57:07	350	1200	PFM350B	903.3	5.23	195.2	Y	c0426115.sam
9/17/2004	16:57:07	350	4800	M68.2	940.8	6.04	194.4	Y	c0426116.sam*

*Monitor hydrophone disabled during transmission.

Station T500 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/18/2004	21:54:25	800	1200	M75(195)	957.7	4.12	193.8	Y	c0426221.sam
9/18/2004	22:54:25	800	1200	M75(195)	952.7	4.08	193.7	Y	c0426222.sam
9/18/2004	23:54:25	800	1200	M75(195)	953.4	4.12	191.9	Y	c0426223.sam
9/19/2004	0:54:25	800	1200	M75(195)	953.8	4.15	191.1	Y	c0426300.sam
9/19/2004	1:54:25	800	1200	M75(195)	954.2	4.15	190.3	Y	c0426301.sam
9/19/2004	2:54:25	800	1200	M75(195)	954.2	4.13	190.1	Y	c0426302.sam
9/19/2004	4:54:25	800	4800	M75(195)	950.3	4.32	194.8	Y	c0426304.sam
9/19/2004	6:54:25	800	1200	M75(195)	950.0	4.34	195.2	Y	c0426306.sam
9/19/2004	7:54:25	800	1200	M75(195)	950.3	4.34	195.1	Y	c0426307.sam
9/19/2004	8:54:25	800	1200	M75(195)	950.2	4.33	195.2	Y	c0426308.sam
9/19/2004	9:54:25	800	1200	M75(195)	950.2	4.32	195.2	Y	c0426309.sam
9/19/2004	10:54:25	800	1200	M75(195)	950.2	4.32	194.7	Y	c0426310.sam
9/19/2004	11:54:25	800	1200	M75(195)	950.6	4.31	195.1	Y	c0426311.sam
9/19/2004	12:54:25	800	1200	M75(195)	950.3	4.30	195.2	Y	c0426312.sam
9/19/2004	14:54:25	350	1200	M68.2	953.8	6.00	193.9	Y	c0426314.sam
9/19/2004	15:54:25	350	1200	PFM350B	915.7	5.24	194.9	Y	c0426315.sam

Station T500 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/19/2004	16:54:25	350	4800	M68.2	953.5	6.05	194.2	Y	c0426316.sam
9/19/2004	18:54:25	350	1200	M68.2	952.6	6.11	194.4	Y	c0426318.sam
9/19/2004	19:54:25	350	1200	M68.2	953.0	6.11	194.2	Y	c0426319.sam
9/19/2004	20:54:25	350	1200	M68.2	953.0	6.11	194.5	Y	c0426320.sam
9/19/2004	21:54:25	350	1200	M68.2	953.0	6.11	194.5	Y	c0426321.sam
9/19/2004	22:54:25	350	1200	M68.2	953.0	6.10	194.5	Y	c0426322.sam
9/19/2004	23:54:25	350	1200	M68.2	952.9	6.09	194.4	Y	c0426323.sam
9/20/2004	0:54:25	350	1200	M68.2	952.3	6.08	194.6	Y	c0426400.sam
9/20/2004	1:54:25	350	1200	M68.2	952.5	6.07	194.6	Y	c0426401.sam
9/20/2004	2:54:25	350	1200	M68.2	953.1	6.07	194.7	Y	c0426402.sam
9/20/2004	3:54:25	350	1200	PFM350B	915.0	5.24	195.2	Y	c0426403.sam
9/20/2004	4:54:25	350	4800	M68.2	953.4	6.02	194.6	Y	c0426404.sam

Station T1000 Transmission Summary									
Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/21/2004	12:48:47	800	1200	M75(195)	957.0	4.17	190.8	Y	c0426512.sam
9/21/2004	13:48:47	800	1200	M75(195)	956.6	4.13	190.3	Y	c0426513.sam
9/21/2004	14:48:47	800	1200	M75(195)	957.0	4.11	190.1	Y	c0426514.sam
9/21/2004	15:48:47	800	1200	PFM800C	769.6	2.71	188.7	Y	c0426515.sam
9/21/2004	16:48:47	800	4800	M75(195)	957.1	4.07	189.9	Y	c0426516.sam
9/21/2004	19:48:47	350	1200	M68.2	952.2	5.92	193.8	Y	c0426519.sam
9/21/2004	20:48:47	350	1200	M68.2	951.4	5.99	194.1	Y	c0426520.sam
9/21/2004	21:48:47	350	1200	M68.2	951.1	6.03	194.2	Y	c0426521.sam
9/21/2004	22:48:47	350	1200	M68.2	950.1	6.05	194.2	Y	c0426522.sam
9/21/2004	23:48:47	350	1200	M68.2	950.6	6.07	194.3	Y	c0426523.sam
9/22/2004	0:48:47	350	1200	M68.2	950.3	6.07	194.4	Y	c0426600.sam
9/22/2004	1:48:47	350	1200	M68.2	950.1	6.08	194.4	Y	c0426601.sam
9/22/2004	2:48:47	350	1200	M68.2	950.0	6.08	194.4	Y	c0426602.sam
9/22/2004	3:48:47	350	1200	PFM350B	912.5	5.23	195.1	Y	c0426603.sam
9/22/2004	4:48:47	350	4800	M68.2	950.4	6.08	194.4	Y	c0426604.sam
9/22/2004	6:48:47	350	1200	M68.2	949.1	6.11	194.6	Y	c0426606.sam

Station T1000 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/22/2004	7:48:47	350	1200	M68.2	949.8	6.11	194.5	Y	c0426607.sam
9/22/2004	8:48:47	350	1200	M68.2	949.7	6.10	N/A	Y	c0426608.sam*
9/22/2004	9:48:47	350	1200	M68.2	950.0	6.10	N/A	Y	c0426609.sam*
9/22/2004	10:48:47	350	1200	M68.2	950.3	6.10	N/A	Y	c0426610.sam*
9/22/2004	11:48:47	350	1200	M68.2	950.4	6.09	N/A	Y	c0426611.sam*
9/22/2004	12:48:47	350	1200	M68.2	950.3	6.09	N/A	Y	c0426612.sam*
9/22/2004	13:48:47	350	1200	M68.2	950.5	6.09	N/A	Y	c0426613.sam*
9/22/2004	14:48:47	350	1200	M68.2	950.4	6.09	N/A	Y	c0426614.sam*
9/22/2004	15:48:47	350	1200	PFM350B	912.9	5.23	N/A	Y	c0426615.sam*
9/22/2004	16:48:47	350	4800	M68.2	950.5	6.07	N/A	Y	c0426616.sam*
9/22/2004	18:48:47	350	1200	M68.2	948.8	6.08	N/A	Y	c0426618.sam*
9/22/2004	19:48:47	350	1200	M68.2	947.4	6.06	N/A	Y	c0426619.sam*
9/22/2004	20:48:47	350	1200	M68.2	950.2	6.07	N/A	Y	c0426620.sam*
9/22/2004	21:48:47	350	1200	M68.2	950.2	6.06	N/A	Y	c0426621.sam*
9/22/2004	22:48:47	350	1200	M68.2	950.1	6.04	N/A	Y	c0426622.sam*
9/22/2004	23:48:47	350	1200	M68.2	950.0	6.02	N/A	Y	c0426623.sam*
9/23/2004	0:48:47	350	1200	M68.2	949.6	5.98	N/A	Y	c0426700.sam*

Station T1000 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/23/2004	1:48:47	350	1200	M68.2	949.7	5.96	N/A	Y	c0426701.sam*
9/23/2004	2:48:47	350	1200	M68.2	950.4	5.95	N/A	Y	c0426702.sam*
9/23/2004	3:48:47	350	1200	PFM350B	912.7	5.18	N/A	Y	c0426703.sam*
9/23/2004	4:48:47	350	4800	M68.2	950.7	5.94	N/A	Y	c0426704.sam*

*Monitor hydrophone unavailable during transmission

Station T1600 Transmission Summary									
Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/24/2004	22:41:54	350	1200	M68.2	949.6	5.91	193.7	Y	c0426822.sam
9/24/2004	23:41:54	350	1200	M68.2	949.0	5.95	194.0	Y	c0426823.sam
9/25/2004	0:41:54	350	1200	M68.2	949.6	5.96	193.8	Y	c0426900.sam
9/25/2004	1:41:54	350	1200	M68.2	950.0	6.01	194.2	Y	c0426901.sam
9/25/2004	2:41:54	350	1200	M68.2	950.1	6.02	194.2	Y	c0426902.sam
9/25/2004	3:41:54	350	1200	PFM350B	912.8	5.21	195.1	Y	c0426903.sam
9/25/2004	4:41:54	350	4800	M68.2	950.6	6.02	194.4	Y	c0426904.sam
9/25/2004	6:41:54	350	1200	M68.2	949.1	5.96	194.1	Y	c0426906.sam
9/25/2004	7:41:54	350	1200	M68.2	950.2	6.00	194.3	Y	c0426907.sam
9/25/2004	8:41:54	350	1200	M68.2	950.3	5.96	194.2	Y	c0426908.sam
9/25/2004	9:41:54	350	1200	M68.2	950.6	5.88	194.3	Y	c0426909.sam
9/25/2004	10:41:54	350	1200	M68.2	951.5	5.70	193.4	Y	c0426910.sam
9/25/2004	11:41:54	350	1200	M68.2	952.8	5.69	191.6	Y	c0426911.sam
9/25/2004	12:41:54	350	1200	M68.2	953.8	5.75	189.3	Y	c0426912.sam
9/25/2004	13:41:54	350	1200	M68.2	953.1	5.68	188.5	Y	c0426913.sam
9/25/2004	14:41:54	350	1200	M68.2	949.9	6.01	194.0	Y	c0426914.sam

Station T1600 Transmission Summary									
Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/25/2004	15:41:54	350	1200	PFM350B	912.0	5.20	194.7	Y	c0426915.sam
9/25/2004	16:41:54	350	4800	M68.2	950.5	6.03	194.2	Y	c0426916.sam
9/25/2004	18:41:54	350	1200	M68.2	948.2	6.05	194.2	Y	c0426918.sam
9/25/2004	19:41:54	350	1200	M68.2	948.8	6.03	194.2	Y	c0426919.sam
9/25/2004	20:41:54	350	1200	M68.2	948.7	5.99	194.4	Y	c0426920.sam
9/25/2004	21:41:54	350	1200	M68.2	948.4	5.96	194.3	Y	c0426921.sam
9/25/2004	22:41:54	350	1200	M68.2	947.2	5.93	194.3	Y	c0426922.sam
9/25/2004	23:41:54	350	1200	M68.2	947.8	5.93	194.2	Y	c0426923.sam
9/26/2004	0:41:54	350	1200	M68.2	948.4	5.92	194.1	Y	c0427000.sam
9/26/2004	1:41:54	350	1200	M68.2	948.8	5.84	194.2	Y	c0427001.sam
9/26/2004	2:41:54	350	1200	M68.2	949.8	5.69	193.6	Y	c0427002.sam
9/26/2004	3:41:54	350	1200	PFM350B	912.8	4.92	192.8	Y	c0427003.sam

Station T2300 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/28/2004	20:34:01	500	1200	M68.2	934.0	5.47	194.6	Y	c0427220.sam
9/28/2004	21:34:01	500	1200	M68.2	937.6	5.45	194.7	Y	c0427221.sam
9/28/2004	22:34:01	500	1200	M68.2	937.3	5.41	194.4	Y	c0427222.sam
9/28/2004	23:34:01	500	1200	M68.2	937.7	5.38	194.5	Y	c0427223.sam
9/29/2004	0:34:01	500	1200	M68.2	937.6	5.35	194.5	Y	c0427300.sam
9/29/2004	1:34:01	500	1200	M68.2	937.5	5.33	194.2	Y	c0427301.sam
9/29/2004	2:34:01	500	1200	M68.2	937.5	5.31	194.5	Y	c0427302.sam
9/29/2004	3:34:01	500	1200	PFM350B	898.0	4.93	195.8	Y	c0427303.sam
9/29/2004	4:34:01	500	4800	M68.2	937.9	5.23	194.3	Y	c0427304.sam
9/29/2004	6:34:01	500	1200	M68.2	940.6	5.30	189.9	Y	c0427306.sam
9/29/2004	7:34:01	500	1200	M68.2	938.1	5.11	193.9	Y	c0427307.sam
9/29/2004	8:34:01	500	1200	M68.2	938.8	5.08	193.0	Y	c0427308.sam
9/29/2004	9:34:01	500	1200	M68.2	936.8	5.50	194.2	Y	c0427309.sam
9/29/2004	10:34:01	350	1200	M68.2	950.0	6.00	193.7	Y	c0427310.sam
9/29/2004	11:34:01	350	1200	M68.2	949.5	6.01	194.1	Y	c0427311.sam
9/29/2004	12:34:01	350	1200	M68.2	949.4	6.07	194.2	Y	c0427312.sam

Station T2300 Transmission Summary									
Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
9/29/2004	13:34:01	350	1200	M68.2	949.6	6.07	194.2	Y	c0427313.sam
9/29/2004	14:34:01	350	1200	M68.2	949.7	6.08	194.1	Y	c0427314.sam
9/29/2004	15:34:01	350	1200	PFM350B	912.0	5.20	195.1	Y	c0427315.sam
9/29/2004	16:34:01	350	4800	M68.2	949.6	6.07	194.1	Y	c0427316.sam
9/29/2004	18:34:01	350	1200	M68.2	948.0	6.06	194.5	Y	c0427318.sam
9/29/2004	19:34:01	350	1200	M68.2	948.4	6.10	194.3	Y	c0427319.sam
9/29/2004	20:34:01	350	1200	M68.2	948.8	6.09	194.3	Y	c0427320.sam
9/29/2004	21:34:01	350	1200	M68.2	949.0	6.09	194.4	Y	c0427321.sam
9/29/2004	22:34:01	350	1200	M68.2	949.3	6.08	194.3	Y	c0427322.sam
9/29/2004	23:34:01	350	1200	M68.2	949.5	6.08	194.4	Y	c0427323.sam
9/30/2004	0:34:01	350	1200	M68.2	949.7	6.07	194.4	Y	c0427400.sam

Station T3200 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
10/2/2004	21:23:52	500	1200	M68.2	949.2	5.56	194.6	Y	c0427621.sam
10/2/2004	22:23:52	500	1200	M68.2	948.3	5.53	194.7	Y	c0427622.sam
10/2/2004	23:23:52	500	1200	M68.2	947.9	5.50	194.6	Y	c0427623.sam
10/3/2004	0:23:52	500	1200	M68.2	947.6	5.48	194.3	Y	c0427700.sam
10/3/2004	1:23:52	500	1200	M68.2	947.1	5.44	194.8	Y	c0427701.sam
10/3/2004	2:23:52	500	1200	M68.2	947.0	5.41	194.8	Y	c0427702.sam
10/3/2004	3:23:52	500	1200	PFM350B	907.9	4.54	196.0	Y	c0427703.sam
10/3/2004	4:23:52	500	4800	M68.2	948.0	5.37	194.5	Y	c0427704.sam
10/3/2004	6:23:52	500	1200	M68.2	947.7	5.16	193.9	Y	c0427706.sam
10/3/2004	7:23:52	500	1200	M68.2	949.7	5.20	192.1	Y	c0427707.sam
10/3/2004	8:23:52	500	1200	M68.2	947.1	5.58	194.4	Y	c0427708.sam
10/3/2004	9:23:52	500	1200	M68.2	947.1	5.55	194.4	Y	c0427709.sam
10/3/2004	10:23:52	500	1200	M68.2	947.2	5.53	194.7	Y	c0427710.sam
10/3/2004	11:23:52	500	1200	M68.2	947.3	5.51	193.9	Y	c0427711.sam
10/3/2004	12:23:52	350	1200	M68.2	947.3	5.50	194.5	Y	c0427712.sam
10/3/2004	13:23:52	350	1200	M68.2	939.7	5.97	193.5	Y	c0427713.sam

Station T3200 Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
10/3/2004	14:23:52	350	1200	M68.2	940.1	5.99	193.9	Y	c0427714.sam
10/3/2004	15:23:52	350	1200	PFM350B	903.0	5.12	195.0	Y	c0427715.sam
10/3/2004	16:23:52	350	4800	M68.2	940.8	5.98	194.3	Y	c0427716.sam
10/3/2004	18:23:52	350	1200	M68.2	940.0	5.96	194.3	Y	c0427718.sam
10/3/2004	19:23:52	350	1200	M68.2	940.2	5.94	194.4	Y	c0427719.sam
10/3/2004	20:23:52	350	1200	M68.2	939.7	5.90	194.4	Y	c0427720.sam
10/3/2004	21:23:52	350	1200	M68.2	939.3	5.87	194.2	Y	c0427721.sam
10/3/2004	22:23:52	350	1200	M68.2	939.4	5.86	194.2	Y	c0427722.sam
10/3/2004	23:23:52	350	1200	M68.2	939.9	5.79	194.1	Y	c0427723.sam
10/4/2004	0:23:52	350	1200	M68.2	940.0	5.78	194.1	Y	c0427800.sam
10/4/2004	1:23:52	350	1200	M68.2	940.2	5.76	194.0	Y	c0427801.sam
10/4/2004	2:23:52	350	1200	M68.2	940.6	5.65	193.8	Y	c0427802.sam
10/4/2004	3:23:52	350	1200	PFM350B	903.2	4.88	193.9	Y	c0427803.sam

Station KAUAI Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
10/8/2004	8:32:33	800	1200	M75(195)	939.5	4.00	194.0	Y	c0428208.sam
10/8/2004	9:32:33	800	1200	M75(195)	938.6	4.04	194.3	Y	c0428209.sam
10/8/2004	10:32:33	800	1200	M75(195)	938.5	4.09	194.4	Y	c0428210.sam
10/8/2004	11:32:33	800	1200	M75(195)	937.9	4.15	194.5	Y	c0428211.sam
10/8/2004	12:32:33	800	1200	M75(195)	937.9	4.16	194.4	Y	c0428212.sam
10/8/2004	13:32:33	800	1200	M75(195)	937.8	4.16	194.4	Y	c0428213.sam
10/8/2004	14:32:33	800	1200	M75(195)	937.7	4.18	194.7	Y	c0428214.sam
10/8/2004	15:32:33	800	1200	PFM800C	753.9	2.76	193.6	Y	c0428215.sam
10/8/2004	16:32:33	800	4800	M75(195)	938.3	4.14	194.5	Y	c0428216.sam
10/8/2004	18:32:33	800	1200	M75(195)	937.0	4.13	194.9	Y	c0428218.sam
10/8/2004	19:32:33	800	1200	M75(195)	937.1	4.12	194.8	Y	c0428219.sam
10/8/2004	20:32:33	800	1200	M75(195)	937.1	4.11	194.6	Y	c0428220.sam
10/8/2004	21:32:33	800	1200	M75(195)	936.9	4.10	194.8	Y	c0428221.sam
10/8/2004	22:32:33	800	1200	M75(195)	939.7	4.10	194.9	Y	c0428222.sam
10/8/2004	23:32:33	800	1200	M75(195)	939.8	4.09	194.8	Y	c0428223.sam
10/9/2004	0:32:33	800	1200	M75(195)	939.6	4.08	194.8	Y	c0428300.sam

Station KAUAI Transmission Summary									
Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
10/9/2004	1:32:33	800	1200	PL800	671.1	2.70	194.5	Y	c0428301.sam
10/9/2004	2:32:33	800	1200	PL800	671.4	2.69	194.3	Y	c0428302.sam
10/9/2004	3:32:33	800	1200	PFM800C	755.5	2.69	193.6	Y	c0428303.sam
10/9/2004	4:32:33	800	4800	M75	940.6	4.03	194.6	Y	c0428304.sam
10/9/2004	0.3142708	500	1200	M68.2	938.7	5.23	194.3	Y	c0428307.sam
10/9/2004	0.3559375	500	1200	M68.2	939.6	4.98	195.1	Y	c0428308.sam
10/9/2004	0.3976042	500	1200	M68.2	940.3	4.86	195.6	Y	c0428309.sam
10/9/2004	0.4392708	500	1200	M68.2	940.4	4.86	195.5	Y	c0428310.sam
10/9/2004	0.4809375	500	1200	M68.2	940.8	4.86	195.7	Y	c0428311.sam
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10/9/2004	20:32:33	350	1200	M68.2	953.5	5.21	195.3	Y	c0428320.sam

Station KAUAI Transmission Summary

Date UTC	Time UTC	Depth [meters]	Duration [seconds]	Signal Type	Cable Voltage	Cable Current	Source Level	Ramp	Filename
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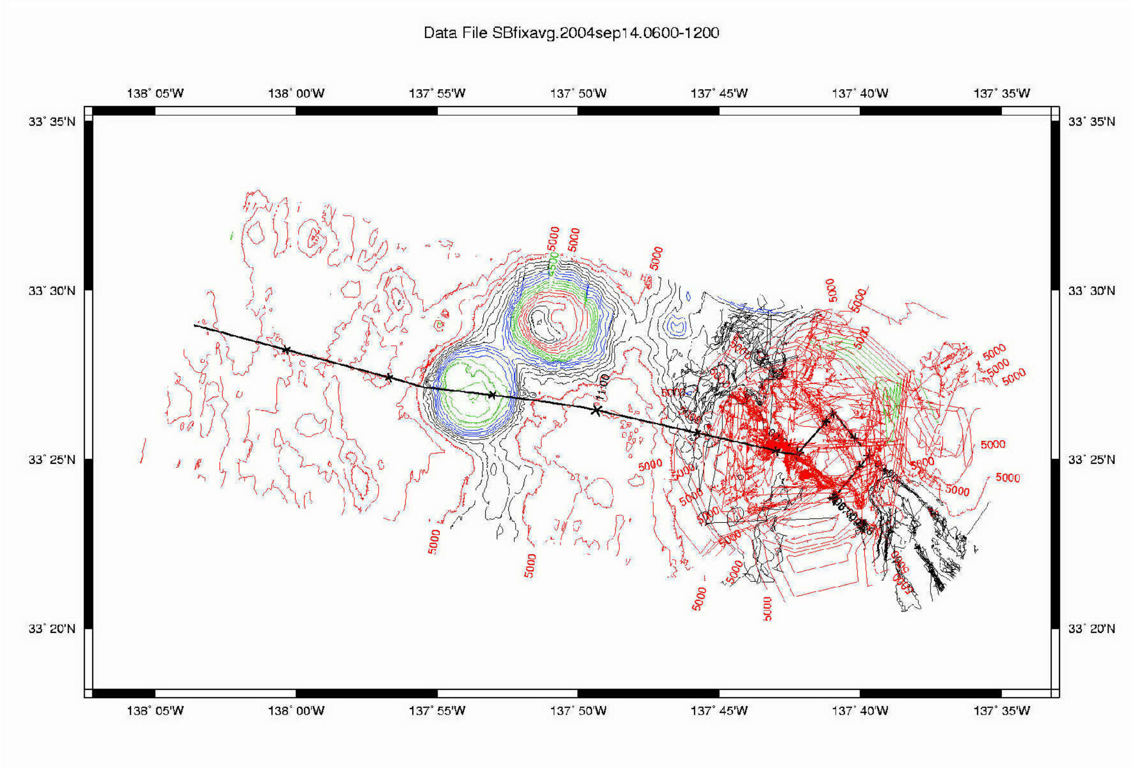
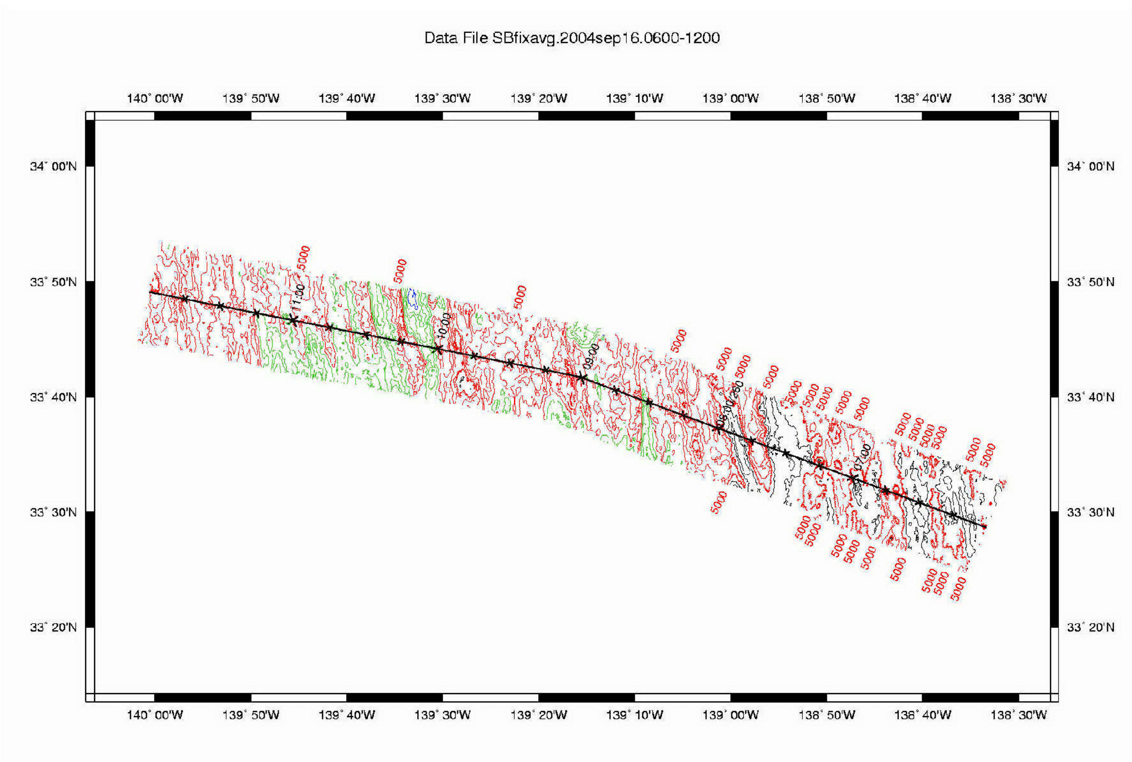
9. Appendix 3: SeaBeam Data





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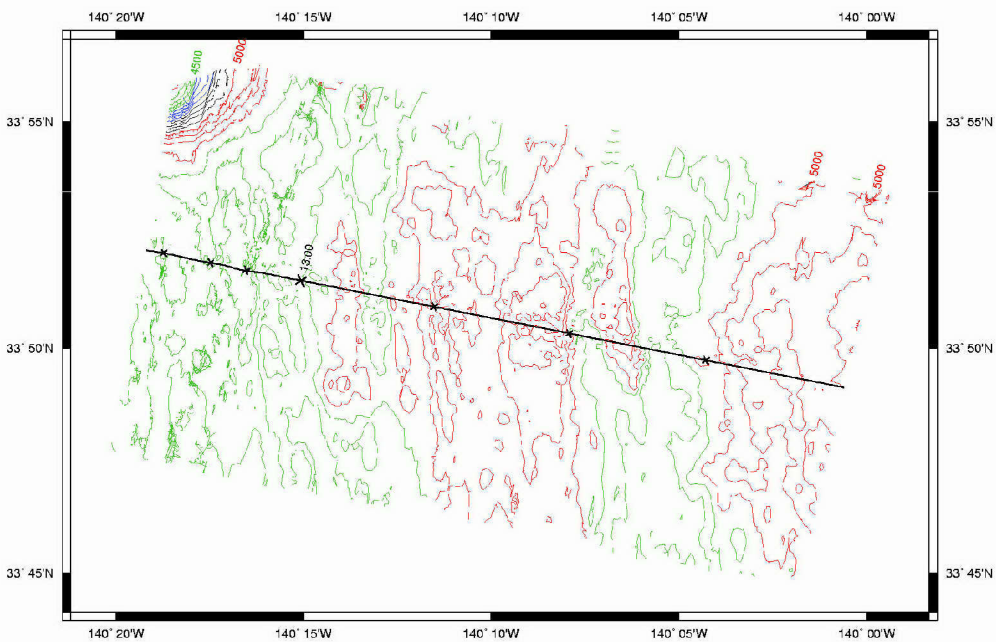

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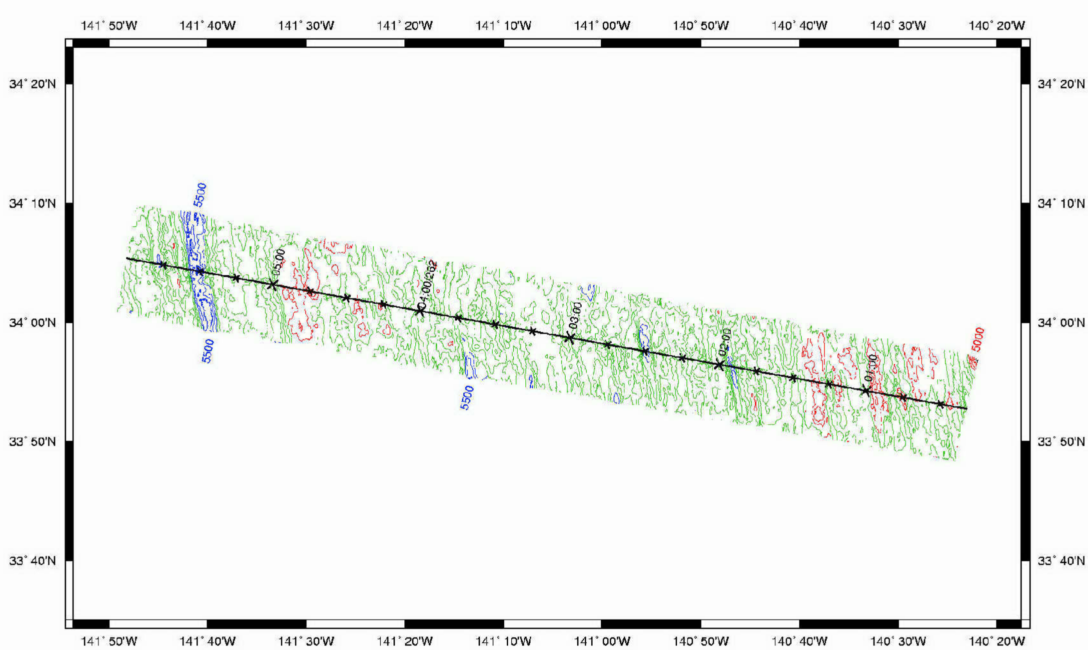

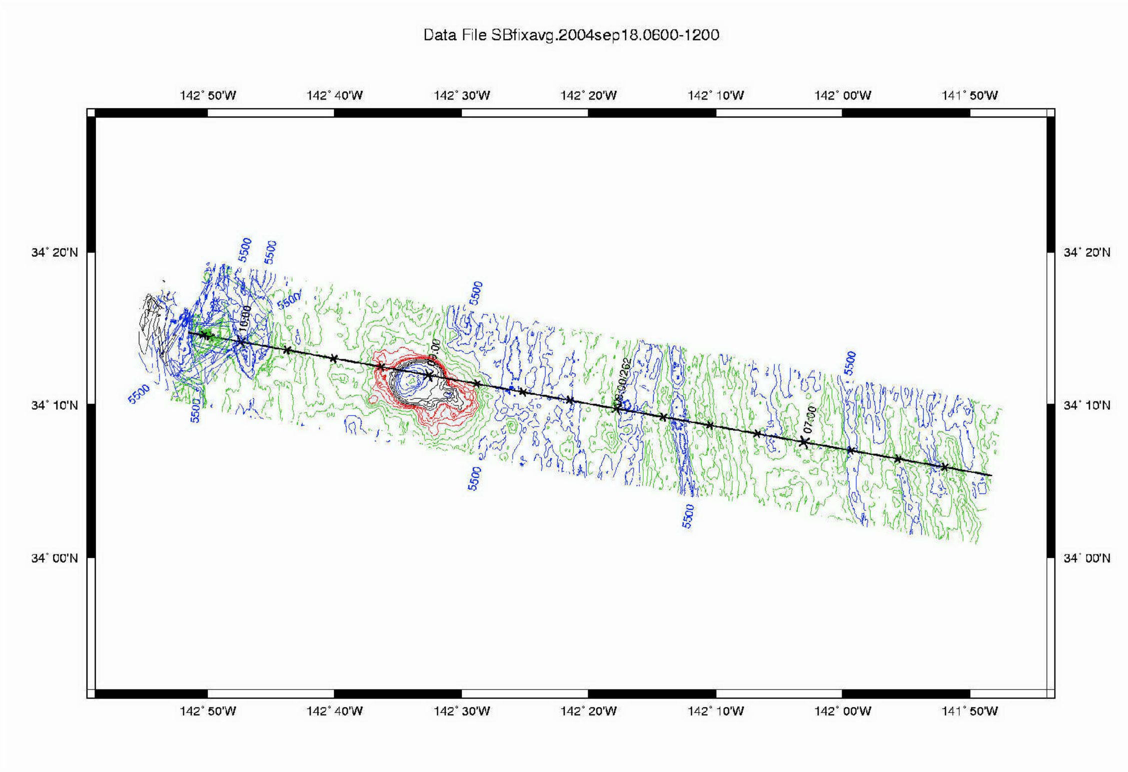
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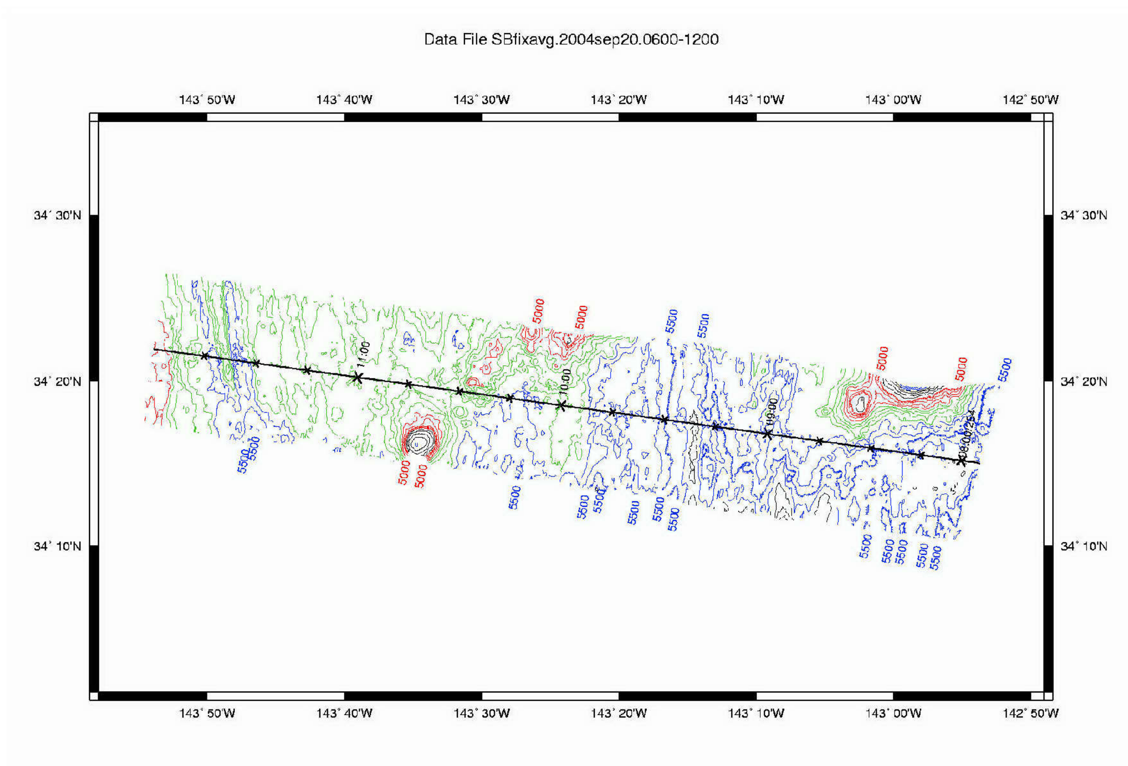
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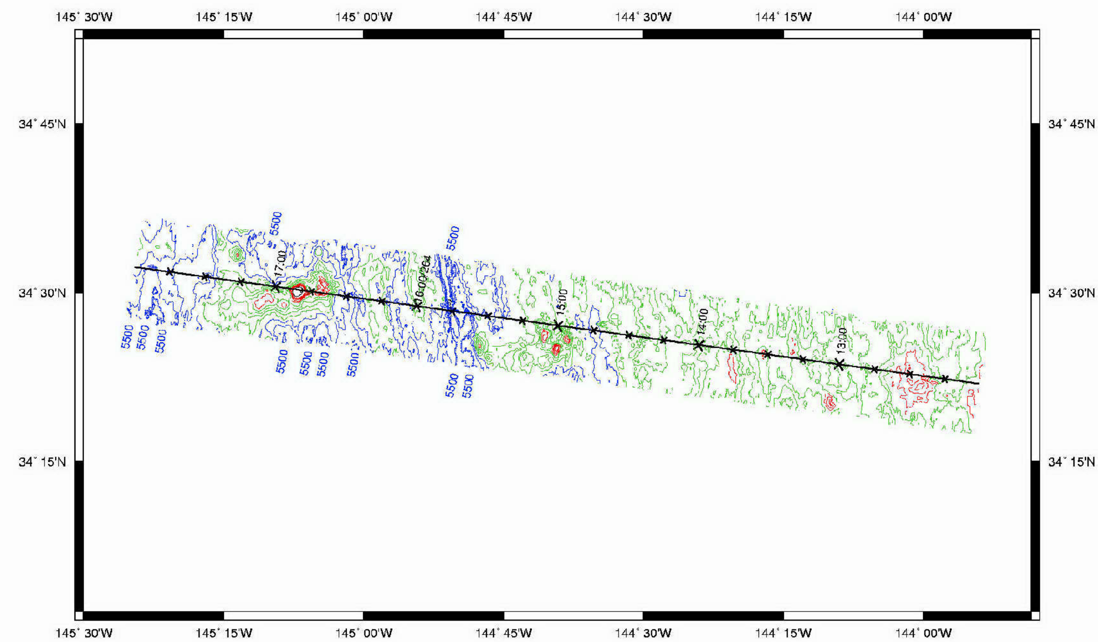

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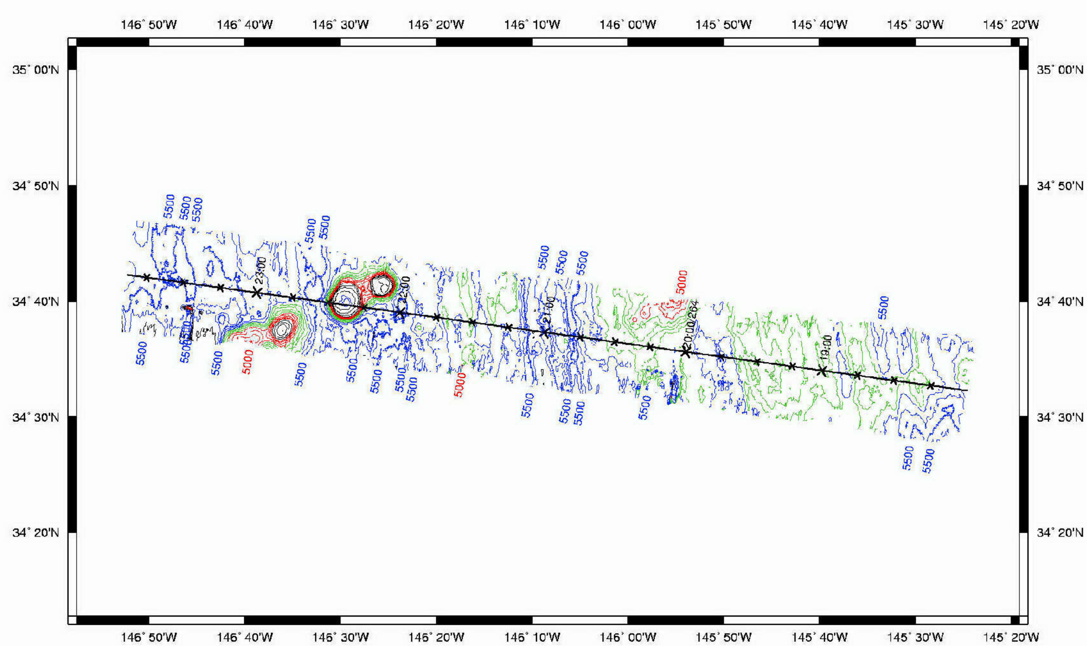

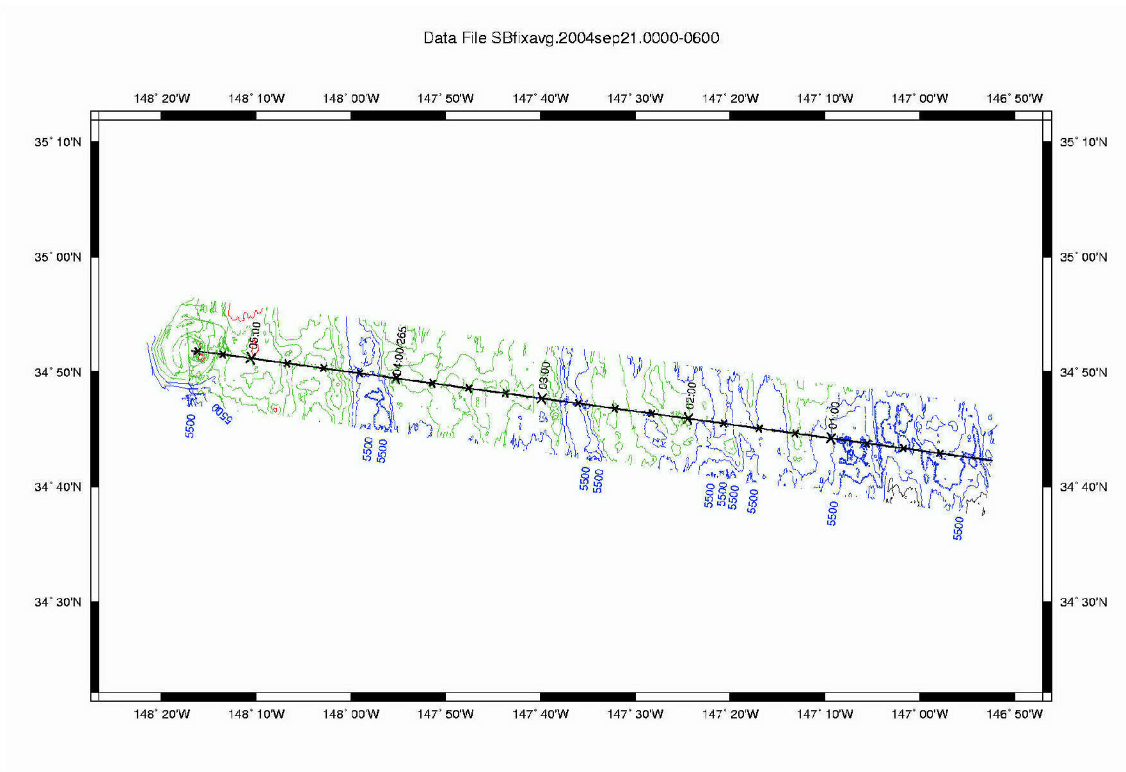
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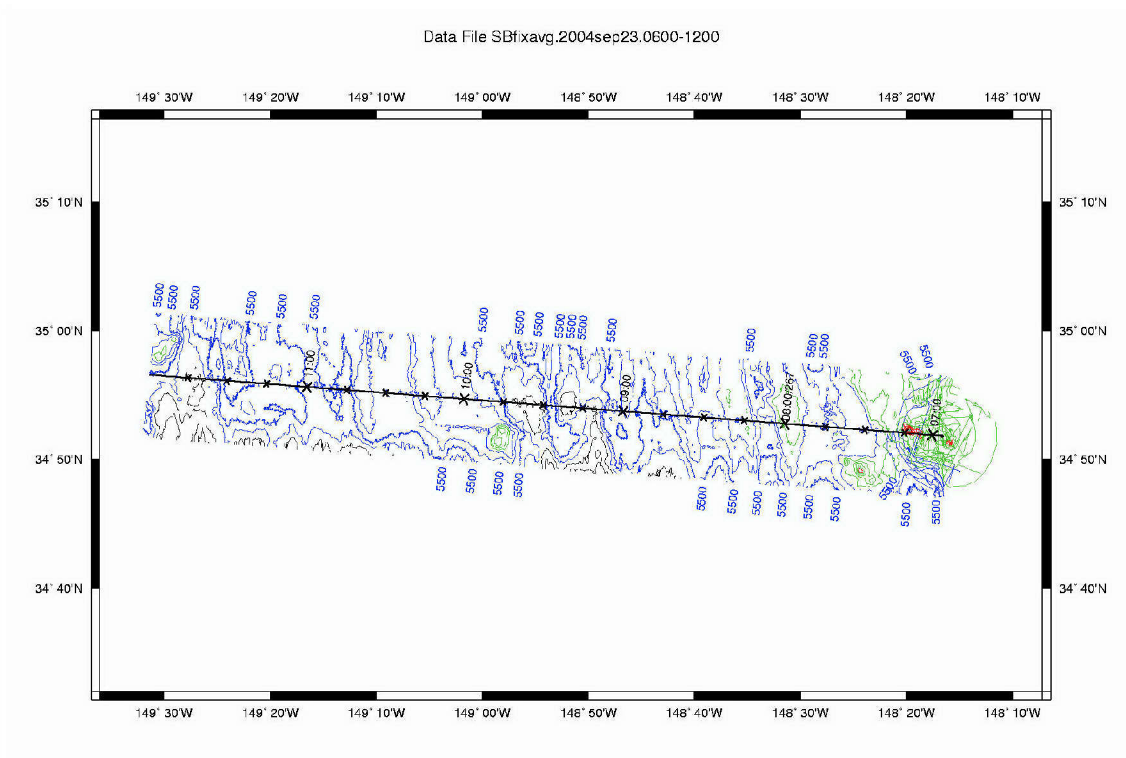
01:00
5500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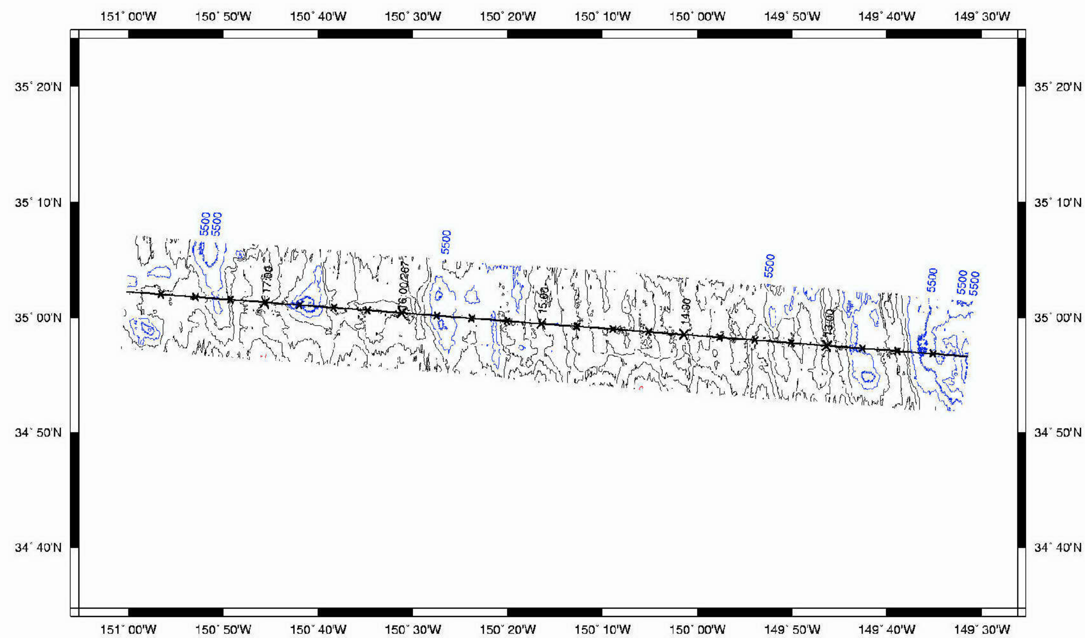

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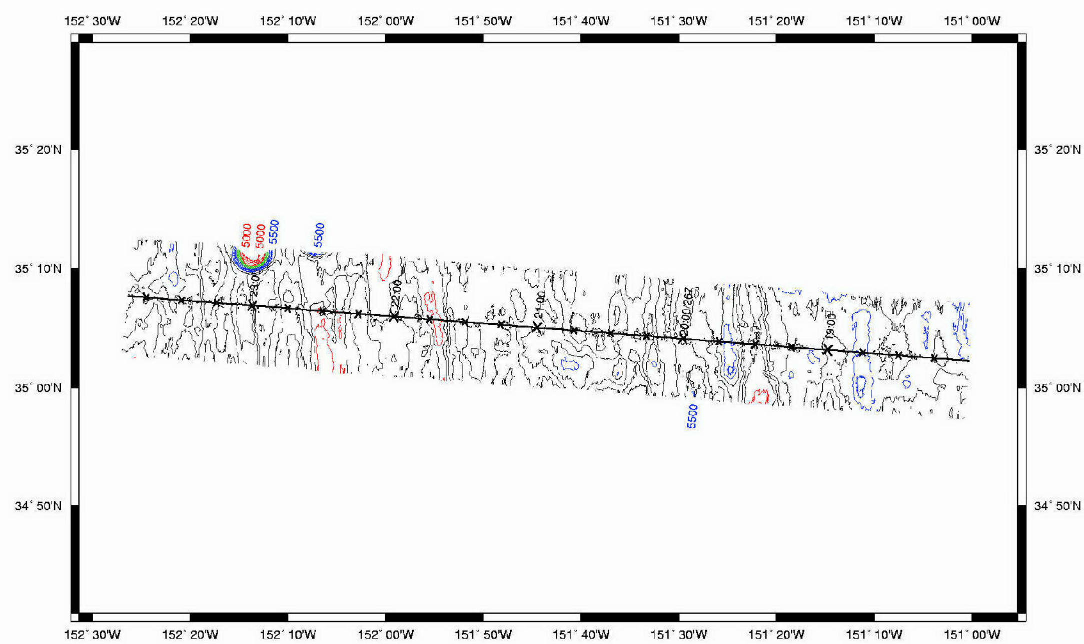

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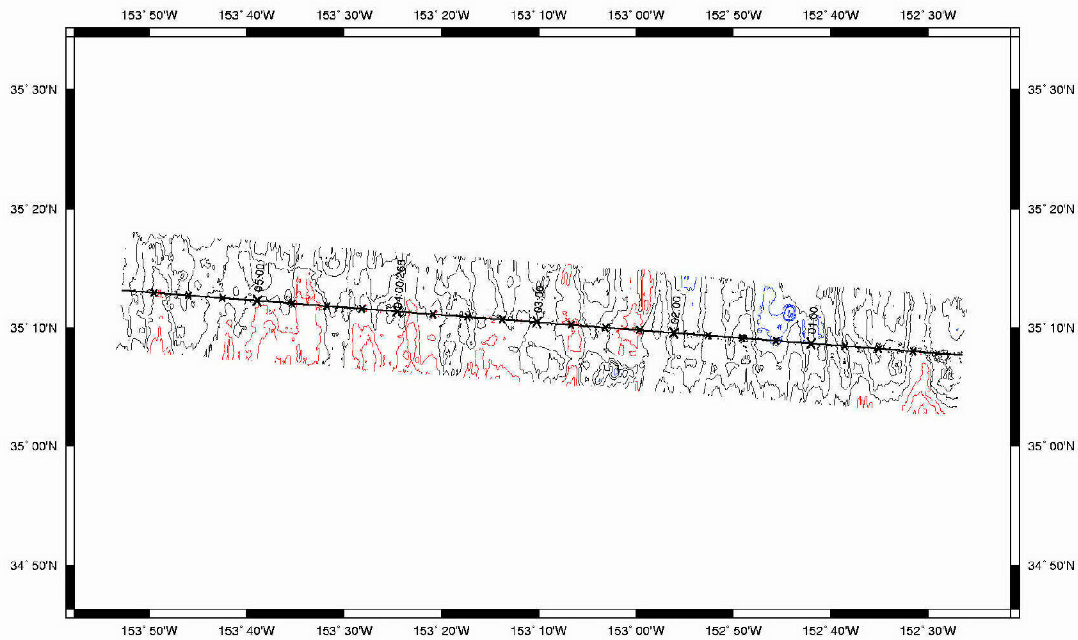

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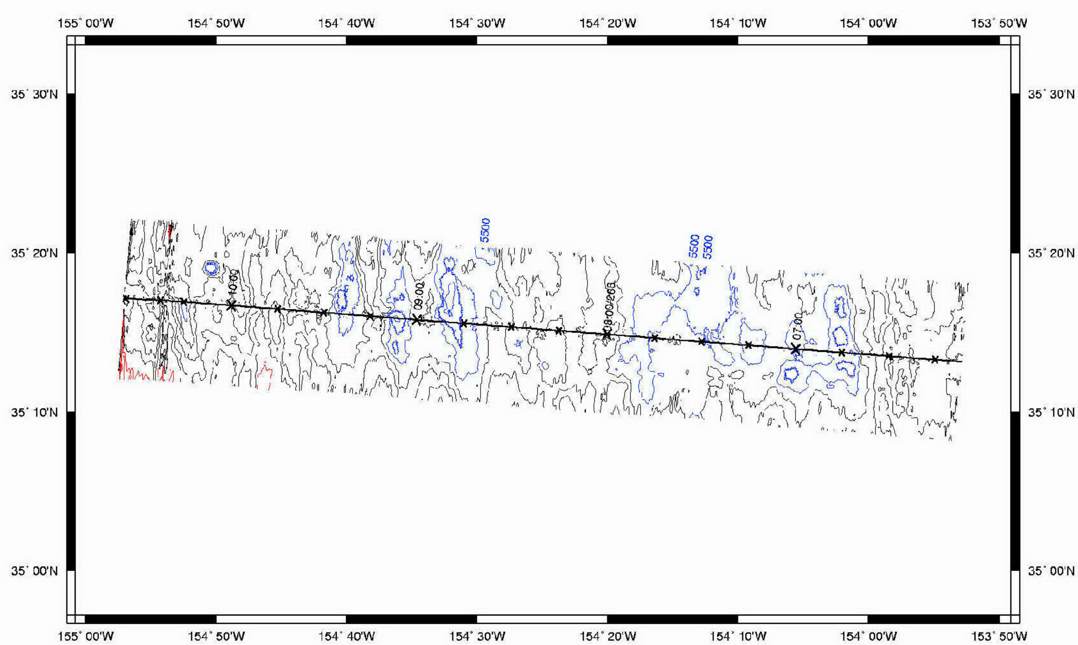

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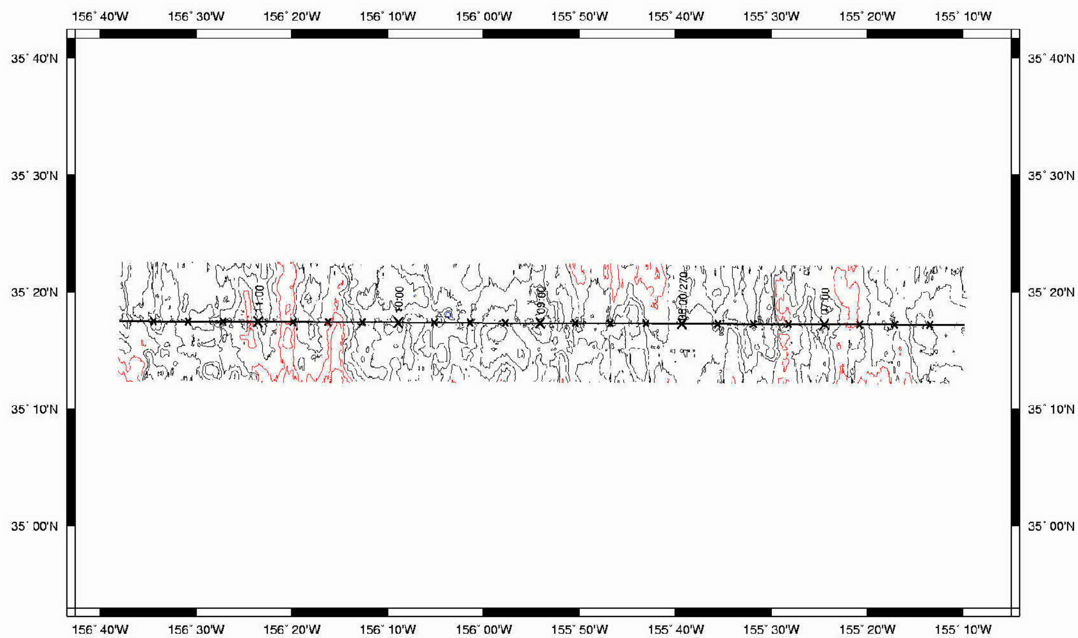

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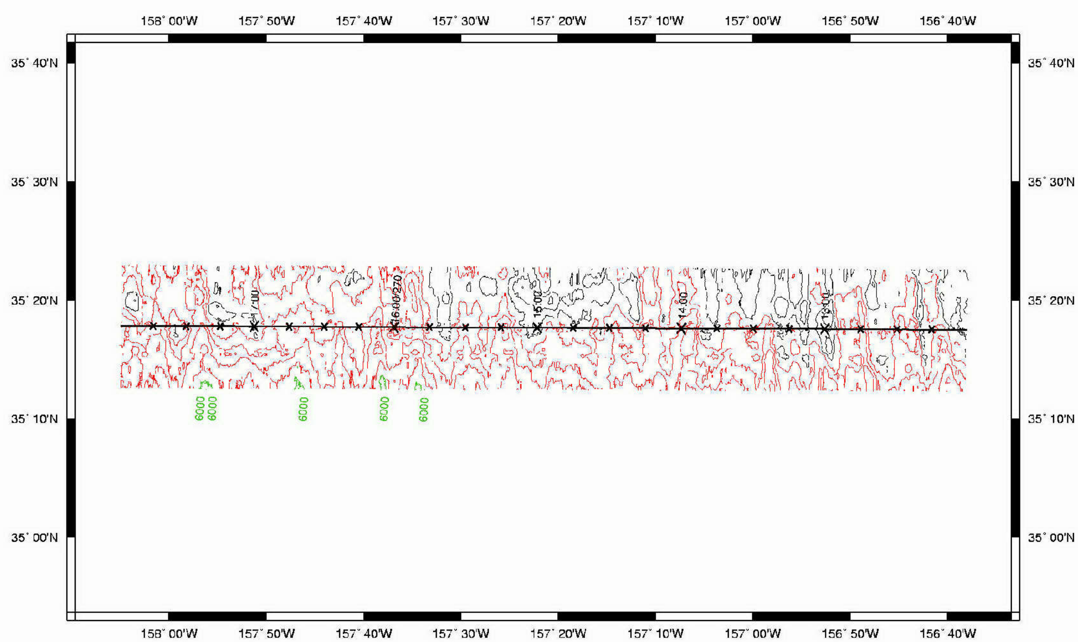

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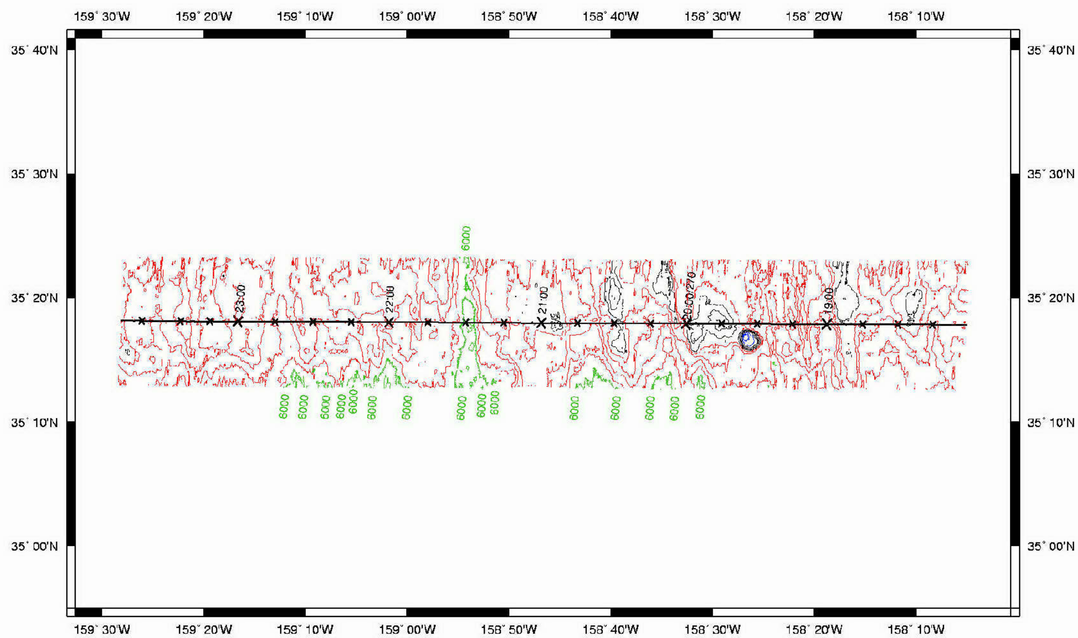

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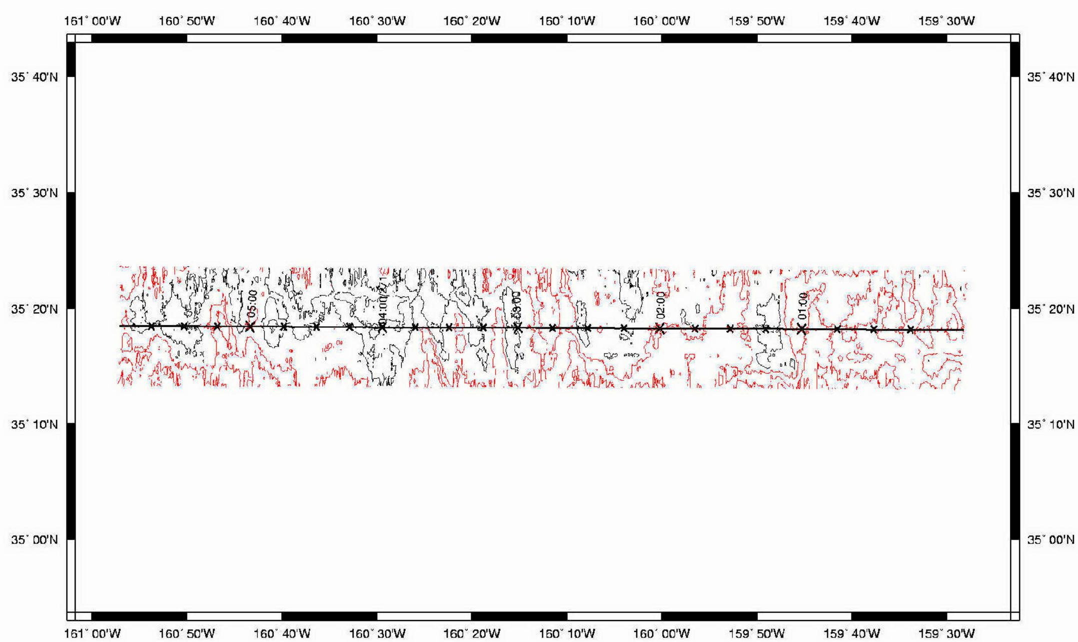

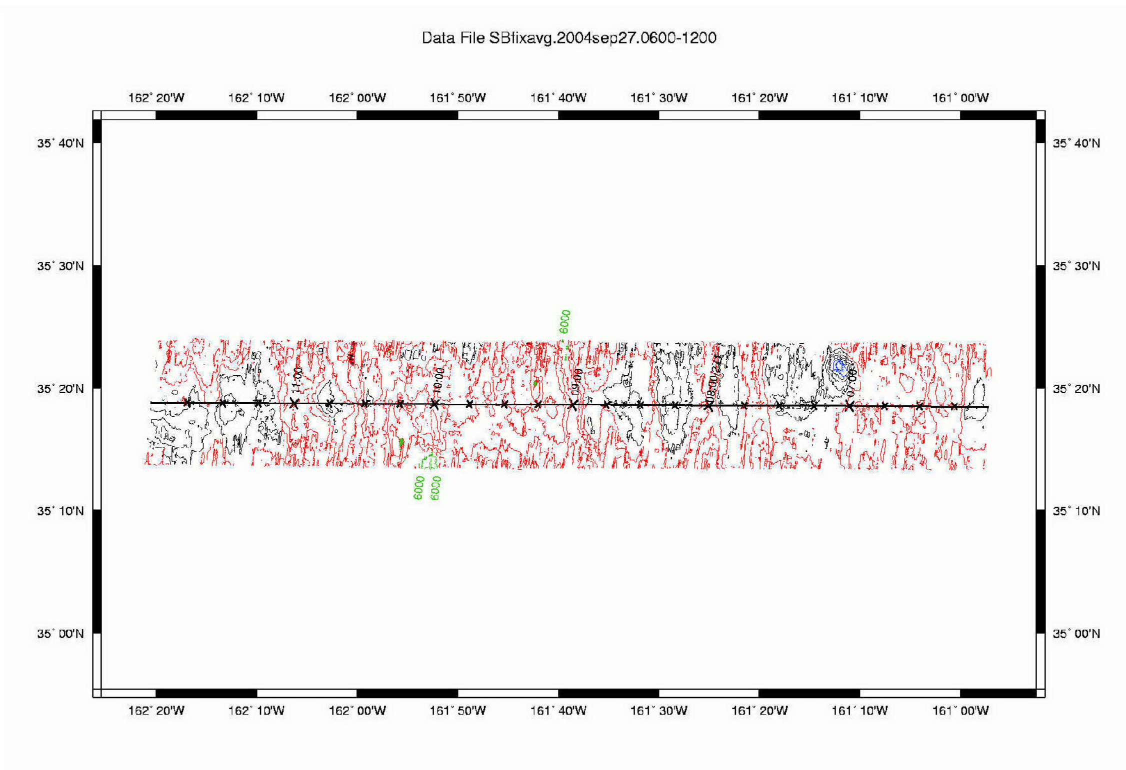
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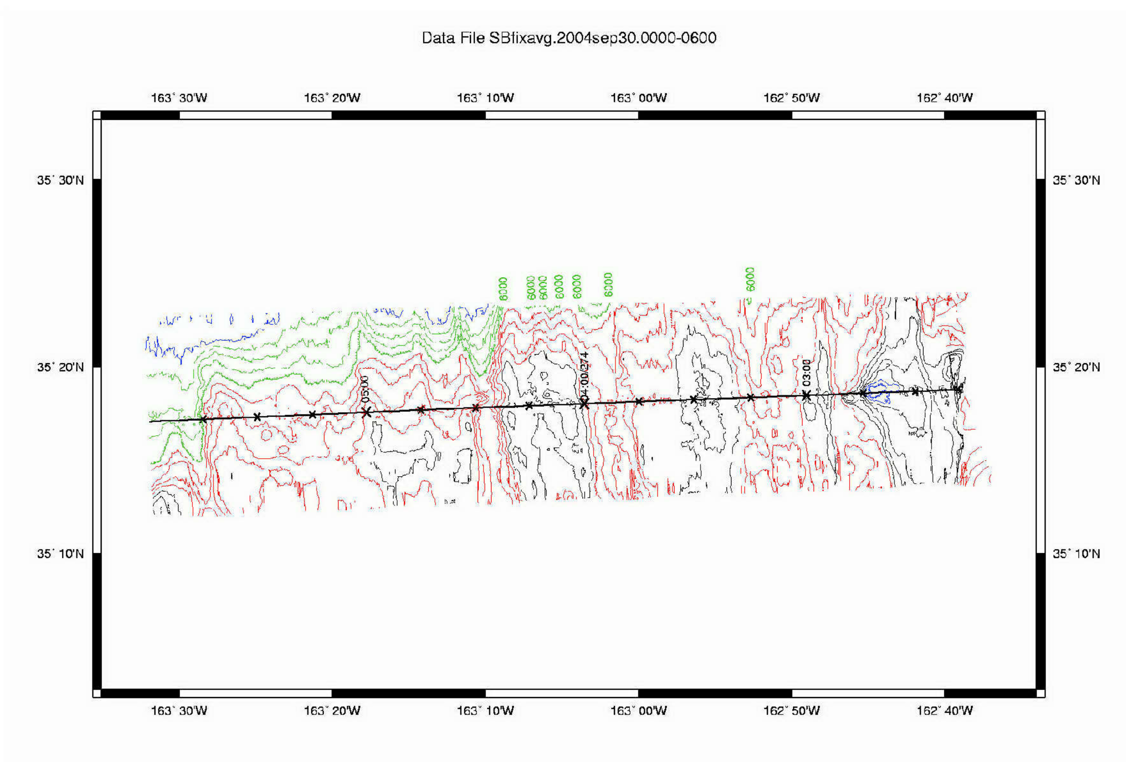
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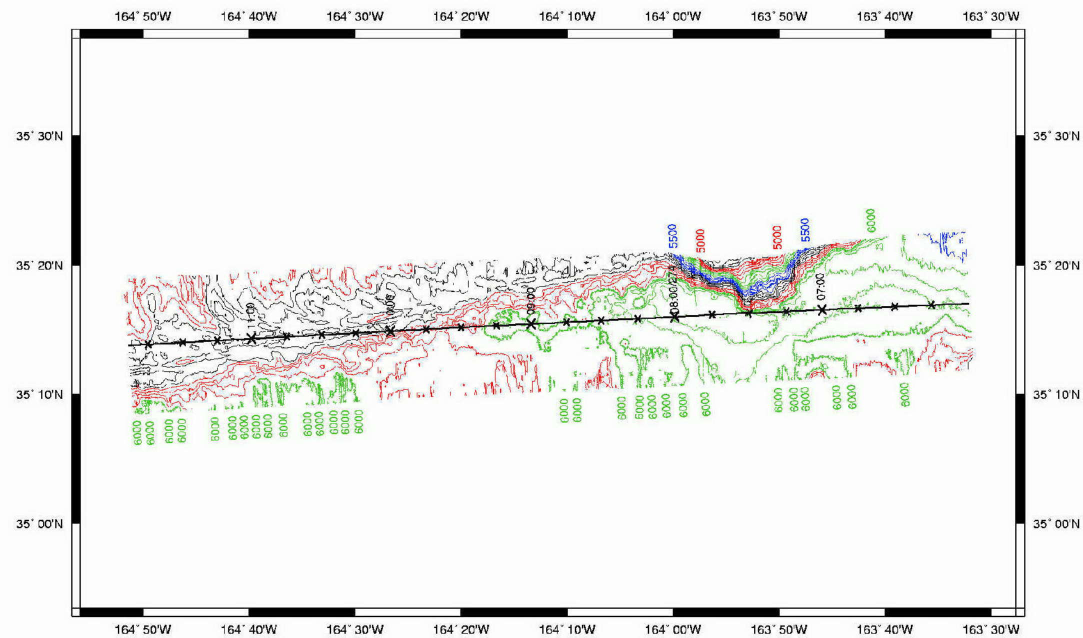

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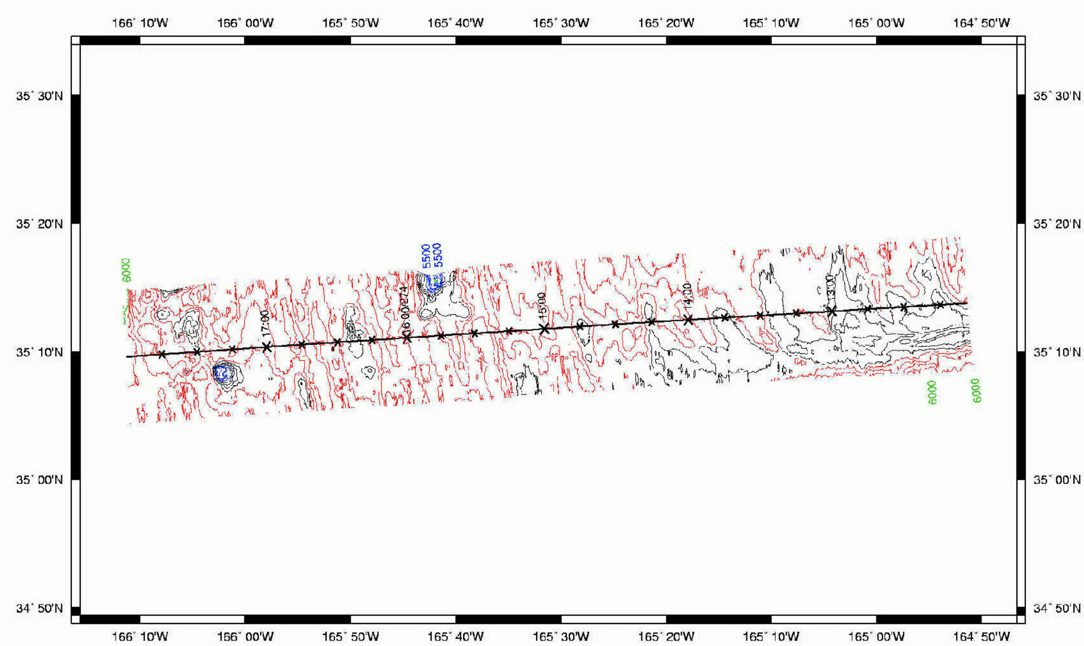

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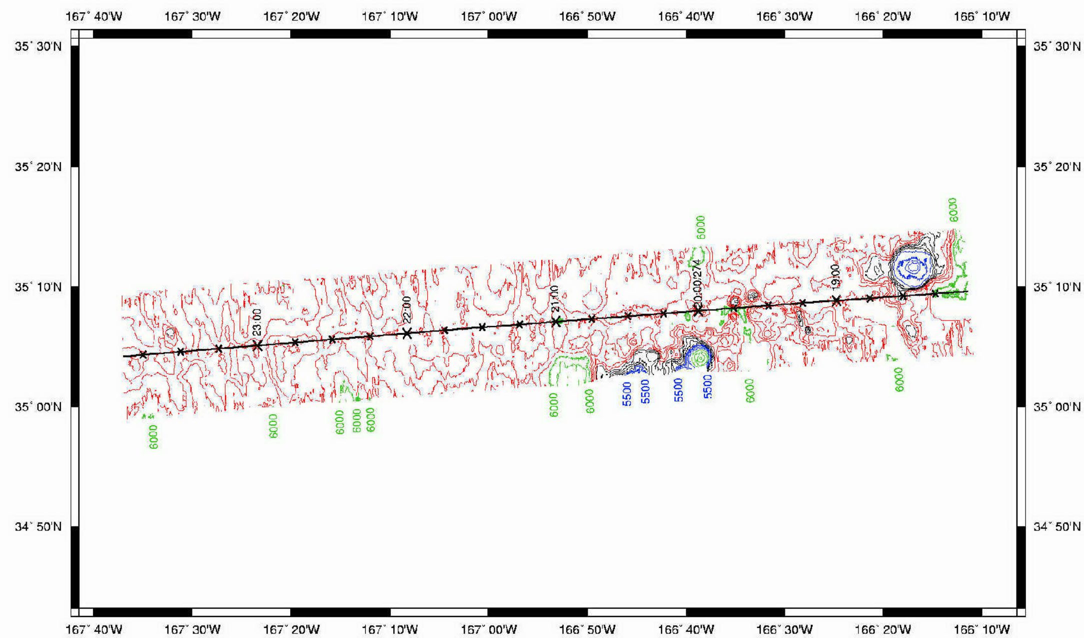

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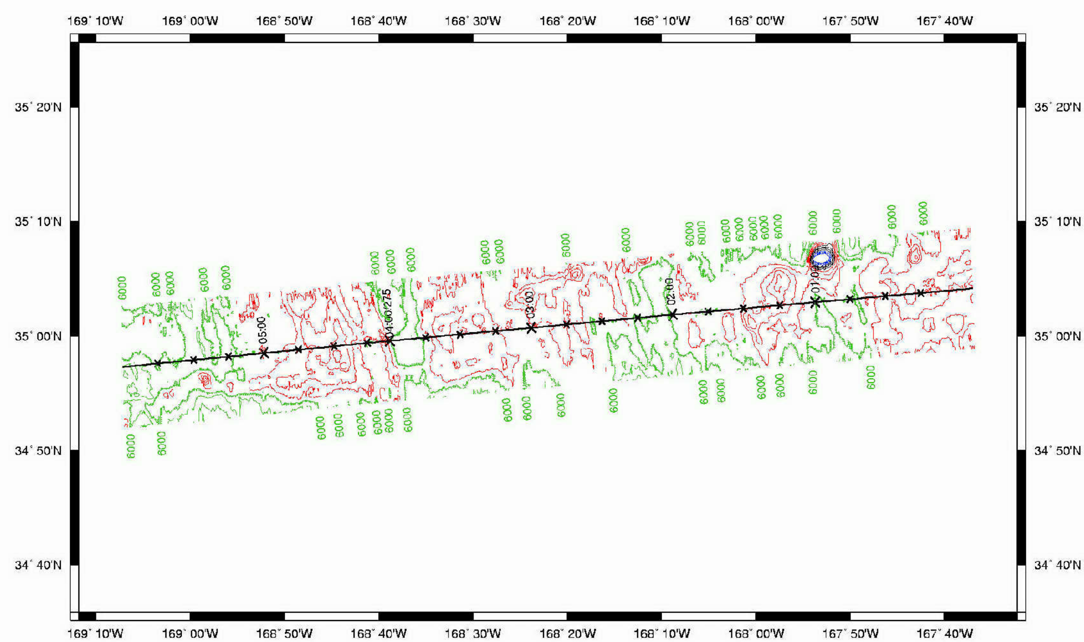

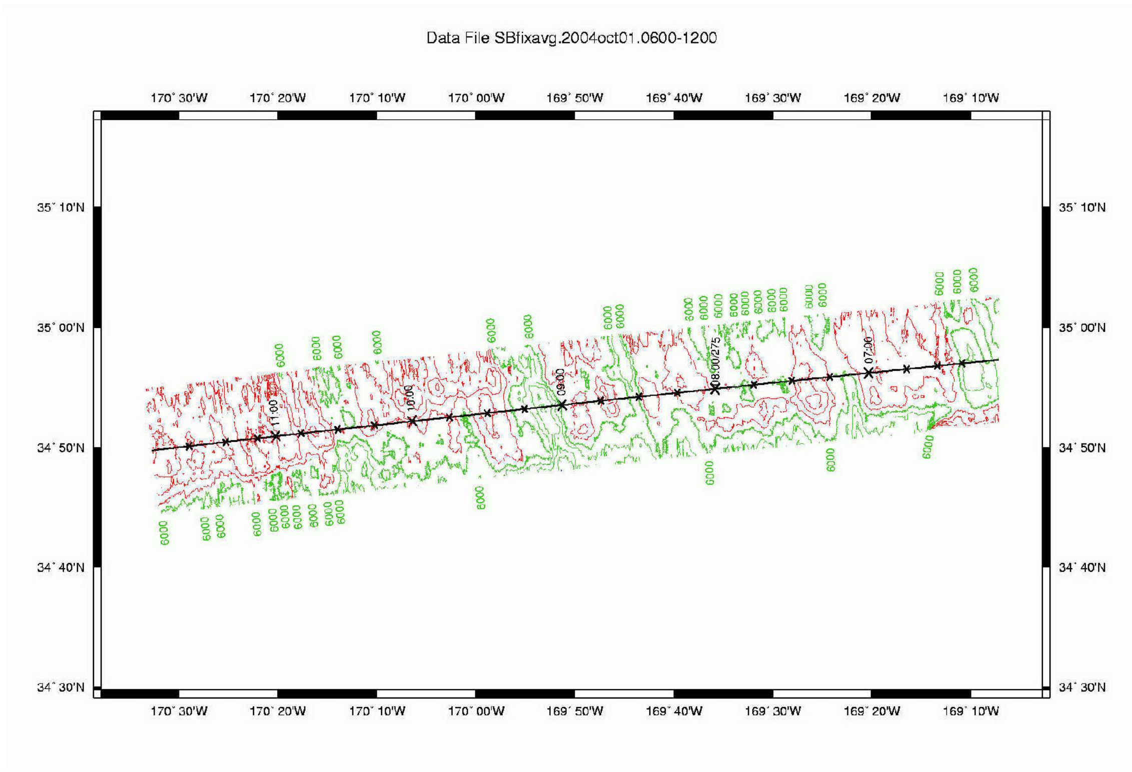
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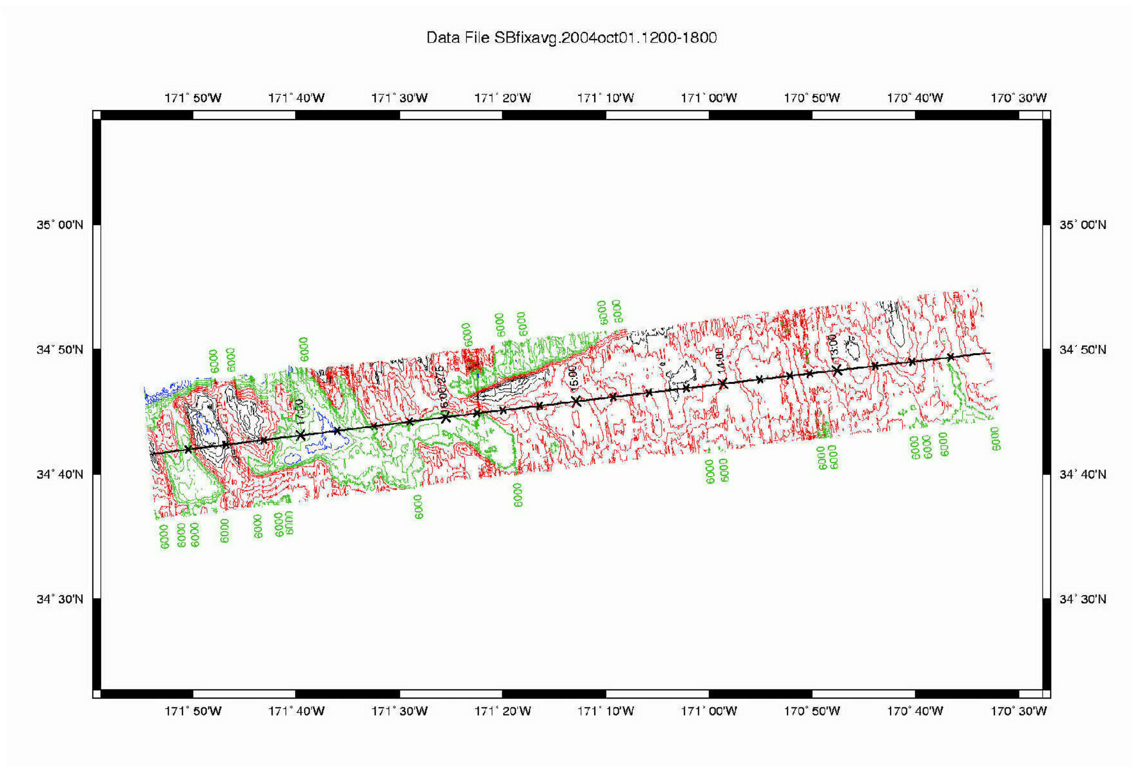
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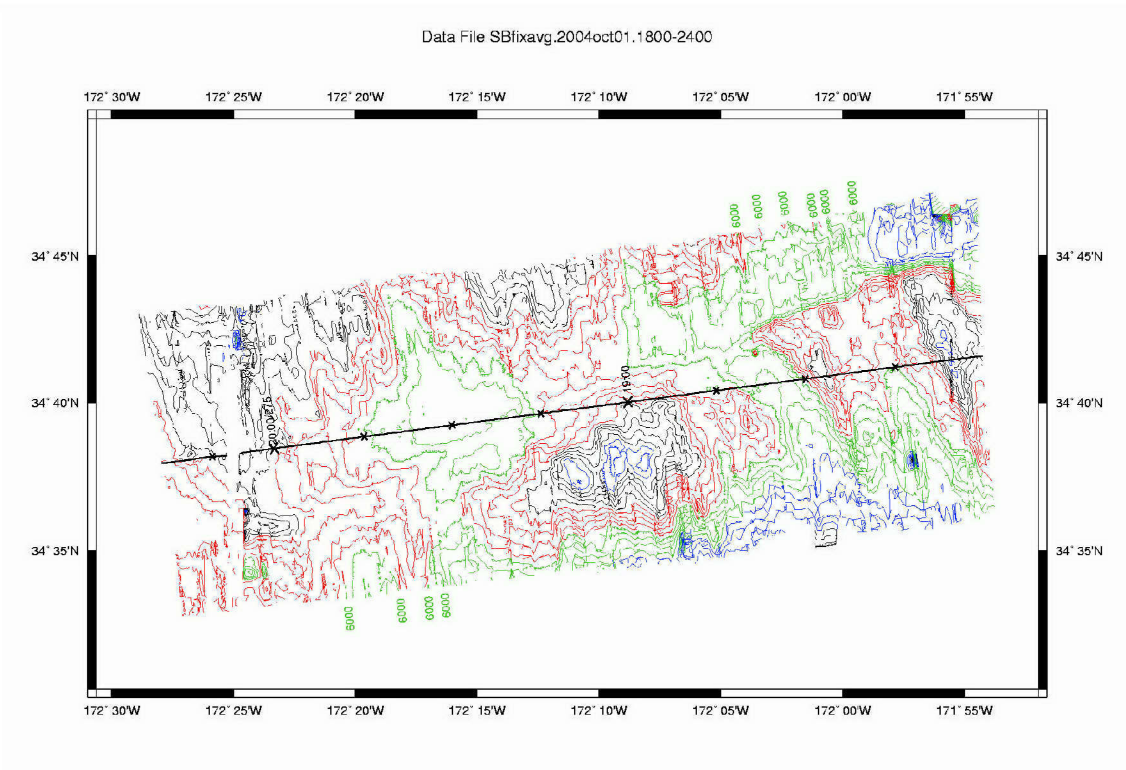
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34° 40'N
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1900
6000

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13. ABSTRACT *(Maximum 200 words)*

This report documents the Long-range Ocean Acoustic Propagation EXperiment (LOAPEX) cruise aboard the R/V *Melville* conducted between 10 September and 10 October 2004. The LOAPEX cruise was coordinated with two other experiments, BASSEX led by Art Baggeroer of the Massachusetts Institute of Technology, and SPICEX led by Peter Worcester of the Scripps Institution of Oceanography. In addition to suspending an acoustic source from the R/V *Melville* at several locations in the eastern Pacific, LOAPEX utilized the North Pacific Acoustic Laboratory (NPAL) assets that were installed by APL-UW during the Acoustic Thermometry of Ocean Climate (ATOC) demonstration. LOAPEX has three primary scientific objectives:

1) to study the evolution, with distance (range), of the acoustic arrival pattern and in particular the range and frequency dependence of the spatial and temporal coherence
2) to determine the effects of the ocean bottom near the NPAL acoustic source located near Kauai, HI
3) to produce a thermal map of the Northeast Pacific Ocean

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14. SUBJECT TERMS
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